

Navy Blue 3G Dye Electrocoagulation using Stainless Steel Electrode in Presence and Absence of Granular Activated Carbon Particle Electrode

Chirag Gohil, Abhipsa R Makwana



Abstract: Textile or dye wastewater is complex and toxic due to presence of complex chemicals in them hence difficult to treat with conventional biological treatment. This paper presents study of electrocoagulation treatment on simulated Navy Blue 3G dye wastewater using stainless steel electrode material in presence and absence of granular activated carbon as particle electrode. Preliminary test to understand effect of initial influent pH (3-10) and NaCl and Na₂SO₄ dose (0-2000 mg/L) on the EC process has also been investigated and further work was carried at optimized initial pH and NaCl dose. The results show that at highest studied current density of 10 mA/cm² with stainless steel electrode showed complete removal of dye concentration after 90 min of treatment time. Electrocoagulation and adsorption using granular activated carbon (GAC) and stainless steel (SS+GAC) are good treatments when dispersed colour is present in the solution. Hence, change in decolourization efficiency of 2D EC was also studied on adding GAC particle electrode between anode-cathode assembly. The effect of current density and dye concentration on colour removal (%) was then studied. Complete removal of colour was observed at lesser time or at more current density; simultaneously initial dye concentration has shown inverse effect on colour removal. Higher removal of around 10 to 15% was reported with SS+GAC compared to SS alone.

Keywords : electrocoagulation, Navy blue 3G, particle electrode.

I. INTRODUCTION

Dye bears complex, molecular structure and resistive to degradation. Efficient treatments for dye before disposal in water bodies are mandatory for sustainable disposal. Dye may be carcinogenic as well as toxic, which reduces light penetration through the water and reduces photosynthesis of aquatic plants and affects aquatic environment.

Environmental risks and legal compulsions force coloured effluent to be treated for benign and toxic organics compound, colour imparting ingredient (dye), as well as for heavy metals substances. Initially dye decolourization was achieved through conventional microbe based treatments, chemical treatments, physicochemical treatments [1,2], while recently advanced oxidation processes and electrochemical treatments are being applied [1]. Physical as well chemical processes bears their disadvantages. Phase transfer is the only phenomena takes place in physical process. Adsorption process recovers dye no adsorbent regeneration. While chemical process needs expensive chemical and also imparts more cost through sludge production. Such sludge also contains toxic or hazardous elements.

Microbe based processes faces difficulties while degrading complex organics where electrochemical processes are observed to be comparatively efficient. Electrocoagulation can be performed using either aluminium or stainless steel as electrode material. Electrocoagulation (EC) has been successfully used to treat the Methylene blue dye [3], simulated and real textile wastewater [4,5]. Hence, decolourization of Navy blue 3G being a dispersed dye can perform well when done with electrooxidation. Hence, the objective of this study was to understand performance of electrocoagulation process efficiency using stainless steel electrode in presence and absence of granular activated carbon as particle electrode.

II. MATERIAL AND METHODS

A. Material

The EC cell was made from 5-mm thick acrylic glass with the dimensions of 100mm×100mm×110mm (width, length, height, respectively). Aluminium and stainless steel were used as electrode material. Cathode and anode were made from rectangular shaped plates with the dimensions of 50mm×100mm×5mm (width, height, thickness, respectively). The total effective electrode area was 55 cm². Current and voltage were controlled by a digital regulated DC power supply (TESTRONIX 92B, 0-32 V, 0-2 A). The distance between the electrodes was kept at 50 mm.

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* Correspondence Author

Dr. Abhipsa R Makwana*, Assistant Professor, Civil Engineering Department (Environmental Section) Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Gujarat, India.

Email: abhipsamakwana78@gmail.com

Chirag Gohil, M.E. Student, Civil Engineering Department (Environmental Section) Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Gujarat, India.

Email: chirag4278.cg@gmail.com

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B. Methodology

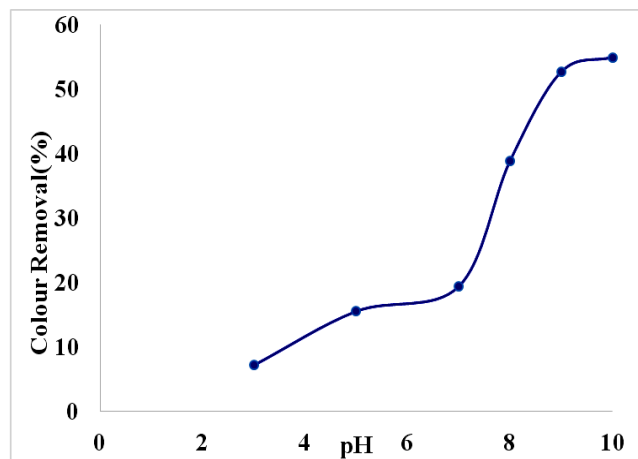
Effect of pH was investigated on varying pH from 3 to 10. Effect of electrolyte dose (NaCl and Na₂SO₄ was carried by varying dose from 0 to 2000 mg/L. Time of electrocoagulation was varied from 0 to 90 min.

Effect of current density was analyzed varying CD from 1 to 10 mA/cm². Effect of dye concentration was analyzed on varying it from 50 to 150 mg/L. All experimental runs were performed at room temperature (25-27°C). Interelectrode distance was kept at 5 cm.

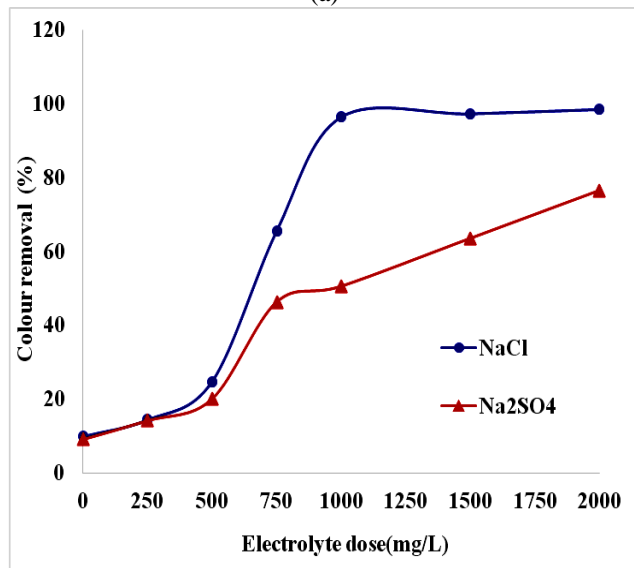
III. RESULT AND DISCUSSION

A. SS Electrode

Effect of pH and electrolyte dose



(a)



(b)

Fig. 1.(a) pH at initial dye concentration 50mg/L, current density-5mA/cm², time -30min (b)Effect of electrolyte dose on % colour removal at initial dye concentration -100mg/L, time -30min, (SS electrode alone)

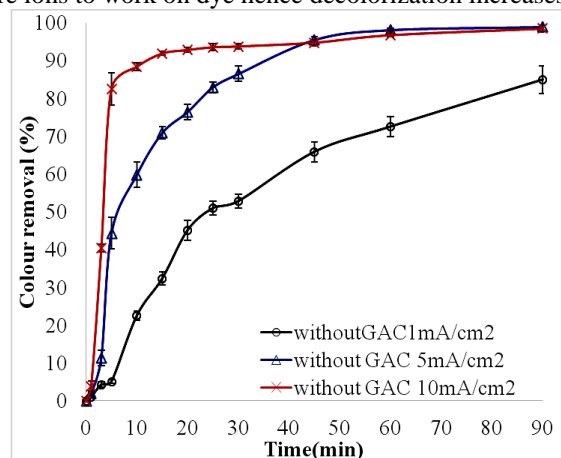
The % colour removal of Navy blue 3g dye was carried out with varying pH such as 3, 5, 7, 8, 9, and 10. Using steel as anode and cathode material. The acidic pH were set up using 1N H₂SO₄ and alkaline pH were set up using 1N NaOH. The initial dye concentration were kept as 50mg/L and operating time were kept as 30 minute for all the pH run. The experiment was carried out and it was observed that at pH 3,

5, 7, 8, 9, and 10 the % colour removal were 7.2%, 15.58%, 19.41%, 38.83%, 52.68% and 54.96% respectively as shown in fig. 1(a). The % colour removal at pH 9 was 52.68% which is optimum of all pH. So all the run has carried out at pH 9.

NaCl and Na₂SO₄ applied with varying them from 0, 250, 500, 750, 1000, 1500 and 2000 mg/L. Dye concentration was kept as 100mg/L, pH was set at 9 using 1NaOH because maximum % colour removal was achieved at this pH. It is operated at 5mA/cm² current density for operating time of 30 minutes. It was observed that with different NaCl dose such as 0, 250, 500, 750, 1000, 1500 and 2000mg/L and % colour removal were found to be 9.91%, 14.43%, 24.78%, 65.51%, 96.44%, 97.3% and 98.49% as shown in Fig 1(b). It was observed that with increasing the electrolyte dose the % colour removal were increasing. NaCl dose increases rate of decolorization. Similar trend has been observed by using Na₂SO₄ (electrolyte) % colour removal was found to be 9.16%, 14.23%, 20.08%, 46.26%, 50.54%, 63.48% and 76.41% for ,250,500,750,1000,1500 and 2000mg/L. It was observed that with increasing the electrolyte dose the % colour removal were increasing and comparing both electrolytes the NaCl gives more % colour removal than Na₂SO₄. Optimum dose gave 96.44% removal with NaCl and 76.41% for Na₂SO₄. So, further all the run has been carried out by using 1000mg/L NaCl dose.

Effect of current density and time

Fig. 2(a, b and c) represent the effects of current density and time on % colour removal at various current densities for the three different initial dye concentration. All the three initial dye concentrations followed similar trend. For example, to achieve 90% or more than 90% colour removal the time required is 90min, 45 min, 15 min for 50mg/L initial dye concentration, 90min., 45 min and 20 min for 100mg/L initial dye concentration, and 90min, 45 min and 20 min for 150mg/L initial dye concentration at 1, 5, and 10mA/cm² current density respectively. It was also observed that beyond optimum time % colour removal were less as there are lesser quantity of dye molecules present in solution which cause increase in cost and consumption of electrodes. EC process efficiency depends on the production of metal ions in the reactor. When electrolysis is carried for longer time imparts more ions to work on dye hence decolorization increases [6].



(a)

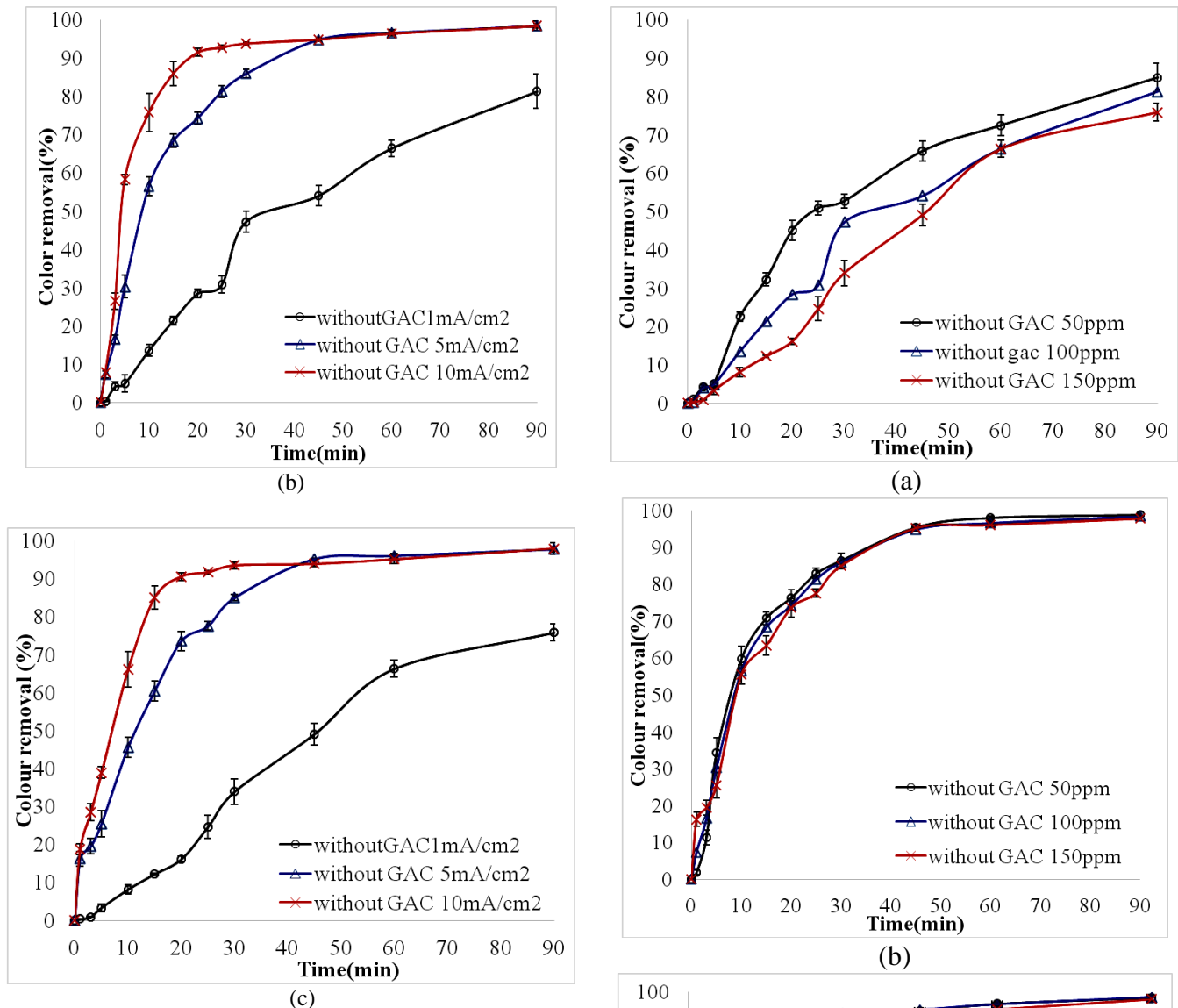


Fig. 2. Effect of CD on % colour removal at initial pH 9, inter electrode distance 5cm for various initial dye concentration, NaCl dose 1000mg/L (a) 50mg/L (b) 100mg/L (c) 150mg/L, using SS electrode

Effect of initial dye concentration

Fig.3 (a, b and c) represent the effects of initial dye concentration and time on % colour removal at various initial dye concentration for the three different current density.

It was observed that the lower is the dye concentration the better is the decolourization efficiency. For example for 30min of operating time at 1mA/cm² CD the % colour removal were found to be 52.77, 47.26 and 33.98% for 50,100and150mg/L initial dye concentration respectively. Similarly, 30min of operating time at 5mA/cm² CD the % colour removal were found to be 82.94, 81.37 and 77.59% for 50,100and 150mg/L initial dye concentration respectively. In Adsorption a Fe hydroxide is the main dye molecule removal pathway. So, for a constant current intensity, there is obviously the equal amount of electro generated SS cations and hence the same amount of coagulating species. More the dye concentration, lesser will be the adsorption sites to capture dye molecules [6].

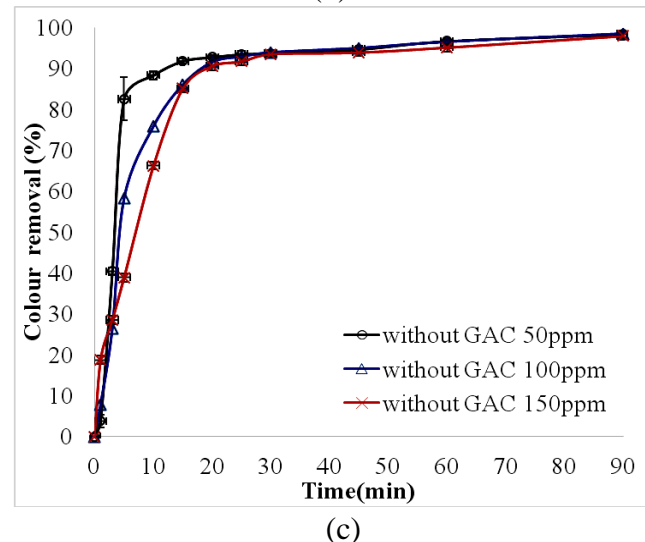
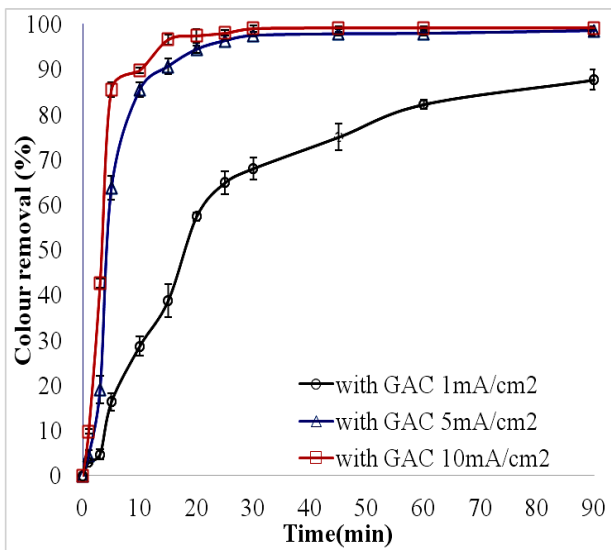


Fig.3: Effect of initial dye concentration on % colour removal at initial pH 9, inter electrode distance 5cm, for various initial dye concentration (a) 1 CD (b) 5 CD (c) 10 CD, using SS electrodes.

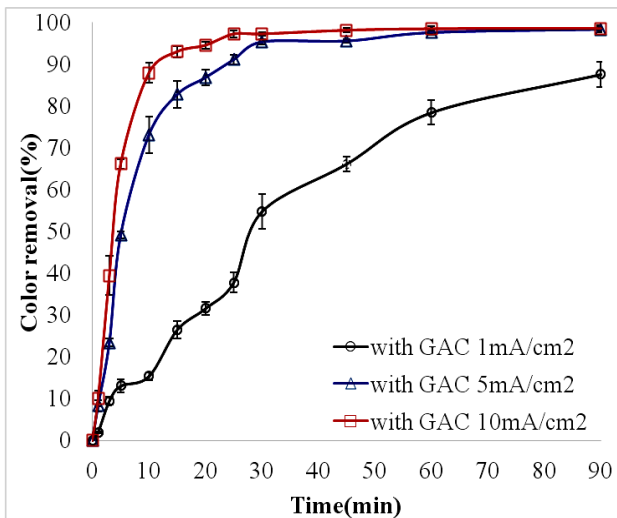
Hence, metal hydroxide flocs get exhausted easily when dye is more. Polar functional group will not be available due to their consumption in dye association this reduces the adsorptive capacity [7].

A. SS and GAC Particle Electrode
Effect of current density and time

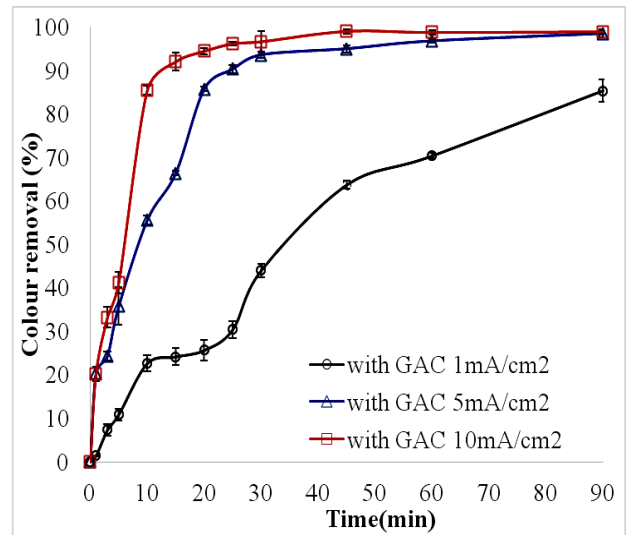
Figure.4 (a, b and c) represent the effects of applied current along with time on % colour removal at various current for the three different initial dye concentration. It was observed that by adding GAC as packed bed the % colour removal efficiency increases compare to without GAC bed because GAC adsorb the dye molecule on its surface and increase the removal efficiency because of the large specific surface area and high porosity, the adsorption of pollutants on particle electrode is inevitable. For example, to achieve 90% or more than 90% colour removal the time required is 30min, 15 min, 5 min for 50mg/L initial dye concentration with GAC as particle



(a)



(b)



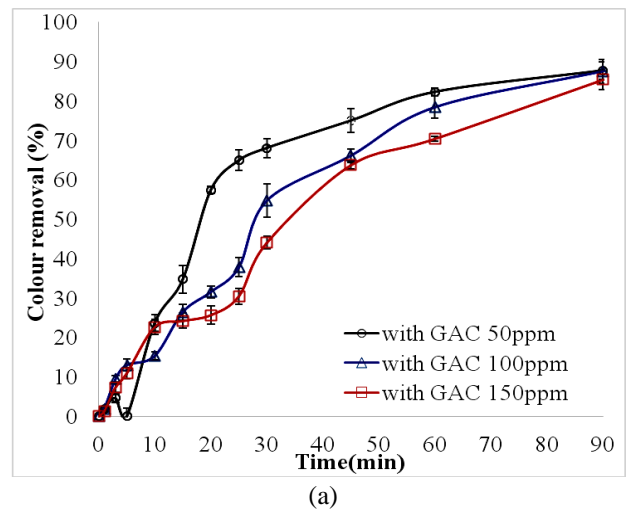
(c)

Fig. 4: Effect of CD on % colour removal at initial pH 9, inter electrode distance 5cm, at various initial dye concentration (a) 50mg/L (b) 100mg/L (c) 150mg/L, using SS +GAC

electrode and for same initial dye concentration and without GAC the time required is 60min, 30min, and 15min at 1,5 and 10mA/cm² current density. Same trend has been observed for all the run as shown in figure.18 (a, b, and c). It was also observed that beyond optimum time % colour removal were less as there are lesser quantity of dye molecules present in solution which cause increase in cost and consumption of electrodes. Combination of electrocoagulation and adsorption combiningly enhanced the organic removal.

Effect of initial dye concentration and time

Figure.5 (a, b and c) represent the effects of initial dye concentration and time on % colour removal at various initial dye concentrations for the three different current density .



(a)

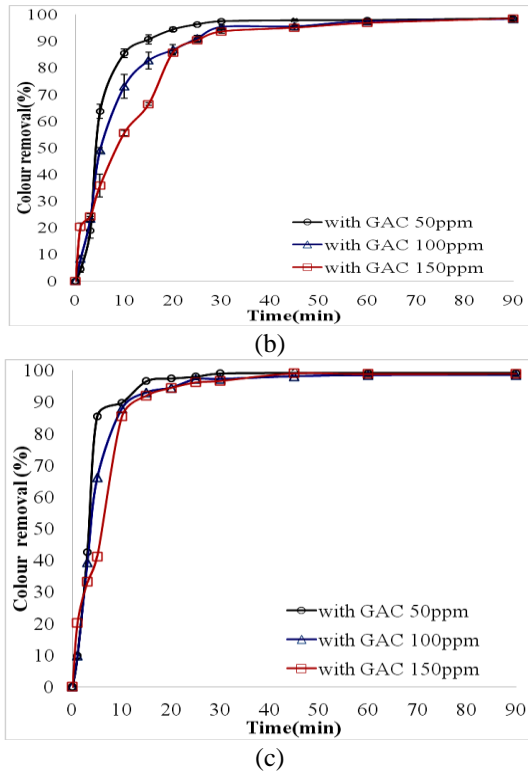


Fig. 5: Effect of initial dye concentration on % colour removal at initial pH 9, inter electrode distance 5cm, for various initial dye concentration (a) 1 CD (b) 5 CD (c) 10 CD, using SS +GAC electrode.

It was observed that the lesser dye showed better decolourization efficiency. For example for 30min of operating time at 1mA/cm² CD the % colour removal were found to be 68.08, 54.74 and 44.04% for 50,100and150 mg/L initial dye concentration respectively. Similarly, 30min of operating time at 5mA/cm² CD the % colour removal were found to 90.69, 82.77, and 66.44% for 50,100 and 150mg/L initial dye concentration respectively. It was also observed that by adding GAC as packed bed the % colour removal were increased at higher initial dye concentration also because the adsorption along with electro sorption effectively promotes the removal of organic pollutants.

Overview of Both the Phases

From the Table. 1 it was observed that when the current density increase the % colour removal increase at constant time and constant initial dye concentration. The same trend has been observed for all the phases and it was also observed that by adding GAC the colour removal efficiency will be more compared to EC done without GAC. From the table it was observed that when the initial dye concentration increases the % colour removal decreases at constant current density and time. The same trend has been observed for both the phase. It has also been observed that GAC particle electrode increases the colour removal efficiency when the initial dye concentration is high .So, the GAC will be more beneficial to perform EC process better even at lower current density and higher initial dye concentration.

Table I: Comparison of SS electrode and SS with GAC particle electrode ,at initial pH -5, Operating time 30minute

Initial dye concentration (mg/L)	Current density (mA/cm ²)	Colour removal (%)	
		SS	SS+ GAC
50	1	81.68	90.27
	5	91.25	99.19
	10	91.91	99.34
100	1	74.75	87.53
	5	90.7	94.42
	10	91.91	97.67
150	1	71.33	85.18
	5	87.81	91.91
	10	91.91	96.53

IV. CONCLUSION

Based on the results of experiments, the following conclusions may be obtained:

The colour efficiency of the simulated Navy blue 3G solution by means of electrocoagulation was affected by the current density, initial pH of the solution, time of electrolysis and different electrode materials.

SS performed well at 1000 mg/L NaCl dose compared to Na₂SO₄ with initial pH 9.

EC using SS electrode the colour removal efficiency will be lower at lower operating time because ions of SS do not liberated easily to achieve higher efficiency higher current density is preferable at 1mA/cm² current density the % colour removal will be 85% and at 5 and 10 mA/cm² current density the % colour removal will be 90% approximately. Further colour removal efficiency decreases as the influent dye concentration increase in the case of SS.

When the GAC has been added as particle electrode the colour removal efficiency will be more than without GAC SS electrode. When the influent concentration is high and current density is low, the EC using SS with GAC particle will be advantageous.

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