A STUDY ON ELECTROCHEMICAL REDUCTION FOR COLOUR REMOVAL OF DYE WASTE

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Abstract: Treatment of wastewater is one of the biggest challenges faced by dye manufacturers. The aim of this study is to check the suitability of electrochemical reduction for the colour removal of dye wastewater and comparison between treatment of live waste and synthetic waste. Electrochemical reduction of dye, acid black 210 was observed in divided cell with the help of the cation exchange membrane. Here as an anode graphite plate was used and as a cathode two plates, graphite and Titanium (Ti) were studied. Sodium sulphate (Na_2SO_4) of analytical standard grade was used as electrolyte. Parameters like initial pH, current density, material of electrode and time for decolourization was studied and optimum condition for colour removal of wastewater was derived. Experiments were run at different current densities like 10,15,20,25,30,40 mA cm^{-2}. For synthetic waste When graphite was used as the cathode, optimum colour removal was 63% at current density of 15 mA cm^{-2} after 120 minutes. Then Ti was used as the cathode, optimum colour removal was 60% at current density of 15 mA cm^{-2} after 120 minutes. For live waste When graphite was used as the cathode, optimum colour removal was 70% at current density of 30 mA cm^{-2} after 120 minutes. Then Ti was used as the cathode, optimum colour removal was 56.28% at current density of 35 mA cm^{-2} after 120 minutes.

Index Terms – Electrochemical reduction, dye wastewater, decolourization

1. INTRODUCTION

Electrochemical remediation method for wastewater treatment is conceived as very effective technology because of its advantages like high efficiency, ambient operating conditions, no sludge generation, smaller equipment size, rapid start up and its use electron which is environment friendly reagent [1]. There are different electrochemical methods like electrochemical reduction, electro-oxidation, electro-coagulation which is widely used in the treatment of wastewater [2-6].

The dye manufacturing industry is one of the leading industries in India. The effluents discharged from these industries if not properly treated, then it can cause serious environmental problems especially on the receiving water bodies. Dye wastewater is characterized by strong colour, a highly fluctuating pH and a high temperature and COD concentration [7-9]. These industries release some chemicals which are highly toxic and non-biodegradable in nature. Other environmental problem that are directly related to dye industries includes air emissions and volatile organic compounds (VOC). Because of all these problems the treatment of these wastewater has become very challenging today. This is a matter of concern as these effluents deteriorate the quality of receiving water bodies.

The colour of wastewater from dye industry varies according to type of dye manufacture or used. This is because of their intensified and dark varieties [10-13]. Colour of dye wastewater can be changed from day by day, or even many times a day. This variation of colour can cause variation in COD also.

The most difficult part of the dye effluent treatment is the strong colour and pH swings. Dye wastewater has a typical characteristic of changing its colour from day to day, or within hours. This variation of colour causes frequent changes in the COD content of the effluents. The pH of effluent that comes from dye industry is very from highly acidic to strong alkaline. Such a large variation in pH can cause problem to chemical treatment process. Therefore, proper pH adjustment is one of the crucial parts of the dye wastewater treatment process.

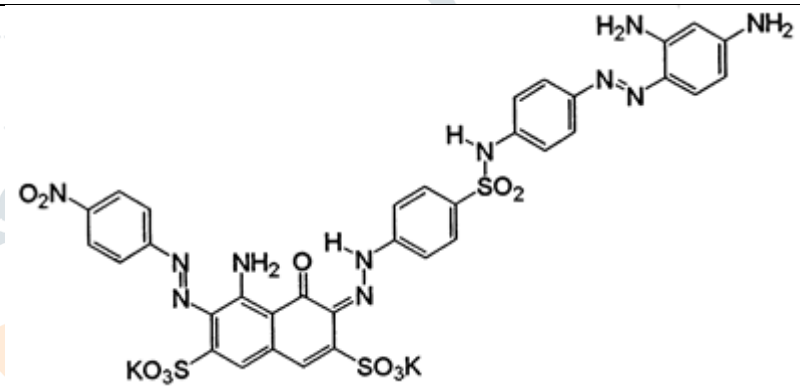
The aim of this study is to check the suitability of electrochemical reduction for the colour removal of dye wastewater. In the electrochemical reduction process, we can get results in terms of colour and biodegradable product. Effect of Different operating variables like, electrode material, pH, current density and the amount of electrolyte etc. on the treatment efficiency were checked. For all this variables, Optimum operating ranges are experimentally determined.

2. MATERIAL AND METHODS

2.1 Chemicals

As an electrolyte sodium sulphate (Na_2So_4) was used. The synthetic solution of dye was prepared with the use of acid black 210. All the solutions were prepared with the use of Distilled water.

Table 1. General characteristic of acid black 210

Parameters	Value
Molecular formula	$C_{34}H_{25}K_2N_{11}O_{11}S_3$
Molecular weight	938.02
Maximum wavelength	459 nm
Molecular structure	

2.2 Material

An electrochemical reduction process conducted with two different cathode materials like graphite and Titanium. Material of anode was graphite.

2.3 Experimental Setup

Electrochemical reduction of acid black 210 dye was performed in divided cell (figure 1) under ambient operating condition using a DC power supply. Glass is used for prototyping. The concentration of acid black 210 was 50 mg/L. In this treatment cation exchange membrane was used for separate study of anode and cathode compartments. Cathode compartment filled with 250 ml of 0.05M Na_2SO_4 solution which contain 50 mg/L of acid black 210. The anode compartment filled with 250 ml of 0.05M Na_2SO_4 solution. Graphite and Titanium plates were used as anode and cathode, which has dimensions of 4 cm x 3 cm and geometric area of 12 cm^2. Distance between two electrodes was maintained to 8 cm. 3.5 ml samples were withdrawn at 10 min. interval and the percentage of decolourization was calculated by equation 1. All the experiments carried out at room temperature (33-35°C). The experiment has been running for 2-hour period.

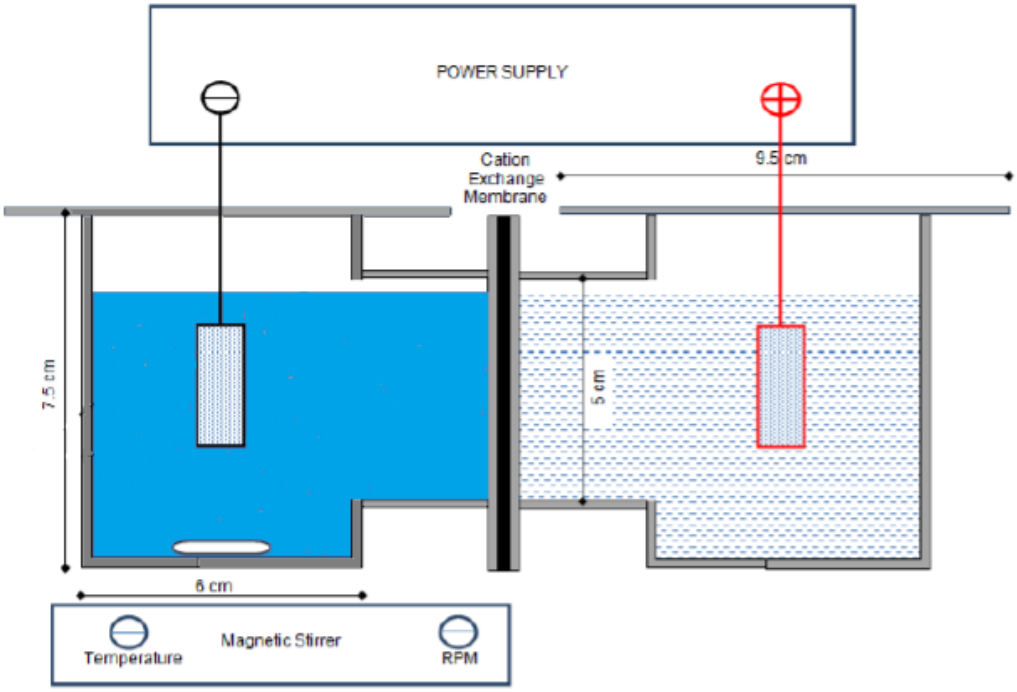


Fig.1 Schematic diagram of ECR Reactor

Source: Popli Snehal, and Upendra D. Patel. "Mechanistic aspects of electro-catalytic reduction of Reactive Black 5 dye in a divided cell in the presence of silver nano-particles." *Separation and Purification Technology* 179 (2017): 494-503. [14]

2.3 Analytical Method

First of all, the initial colour of the Sample was measured before commencement of treatment with the help of Spectro photometer**.** After that colour of the sample that taken at different interval was measured. % Acid black 210 decolourization was calculated as given in equation 1.

$$\% \text{ Acid black 210 decolourization} = \frac{C_0 - C}{C_0} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where C_0= Initial colour at time t_0

C= colour at time t

3. RESULTS AND DISCUSSION

3.1 FOR TREATMENT OF SYNTHETIC WASTE FOLLOWING RESULTS ARE OBTAINED

3.1.1 Electrochemical reduction of acid black 210 at current density of 10 mA cm^{-2}

Time-dependent profiles of AB210 decolourization with the help of Titanium electrode and graphite electrode were as shown in Figure 2 & Figure 3 respectively. When Titanium was used as a cathode percentage decolourization was 46% and in the case of graphite percentage decolourization was 62.33%. Before the treatment started initial pH of catholyte was noted, it was 7 and as the process going on pH increased up to 11, attributed to reduction of H_2O to hydrogen, accumulating the hydroxyl ions.

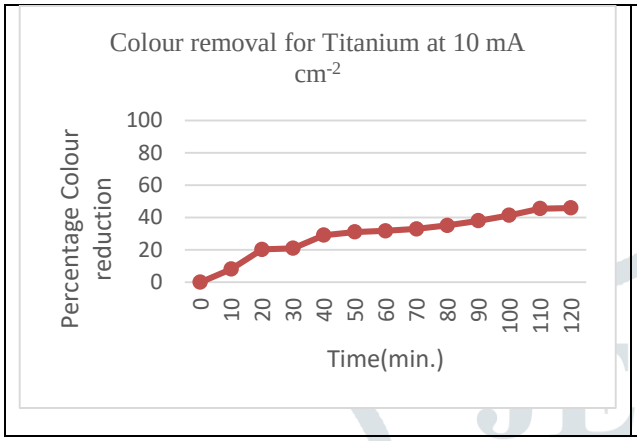


Fig.2 colour reduction 45.94%

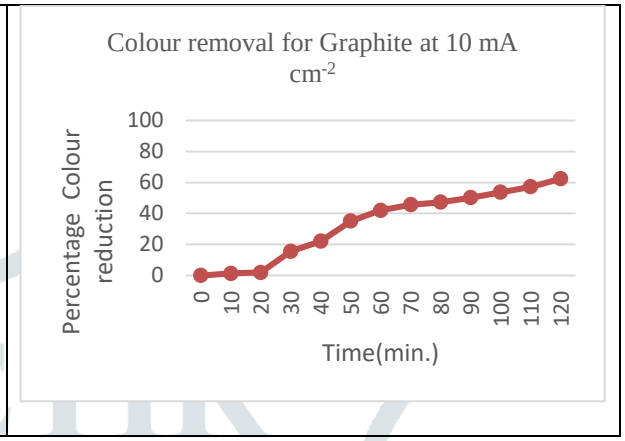


Fig.3 colour reduction 62.33%

3.1.2 Electrochemical reduction of acid black 210 at current density of 15 mA cm^{-2}

As the current density increase from 10 to 15 mA cm^{-2} rate of removal of colour was also increased because of the amount of hydrogen radical that directly attack on the dye molecules was also increased. When Titanium was used as a cathode percentage decolourization was 60% and in the case of graphite percentage decolourization was 63%.

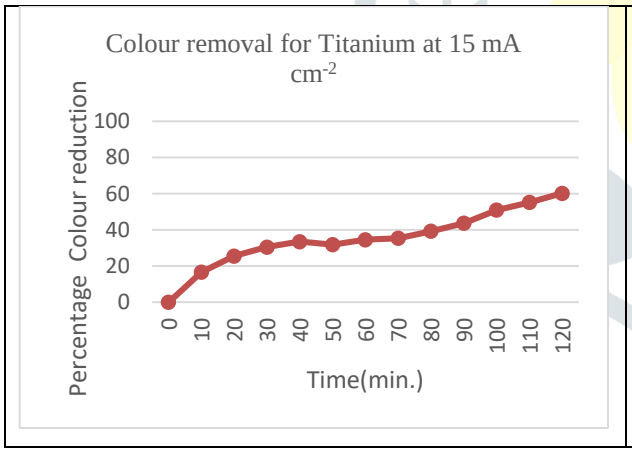


Fig. 4 colour reduction 60.19%

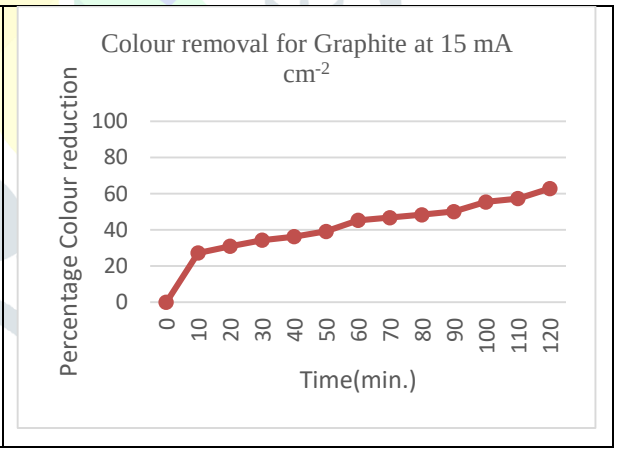


Fig. 5 colour reduction 62.90%

3.1.3 Electrochemical reduction of acid black 210 at current density of 20 mA cm^{-2}

It was noted that at current density of 20 mA cm^{-2} for the Titanium cathode colour reduction was almost same that was at 15mA cm^{-2}. But for graphite cathode there was reduction in colour removal efficiency. For Titanium cathode percentage decolourization was 60.1% and in the case of graphite percentage decolourization was 47%.

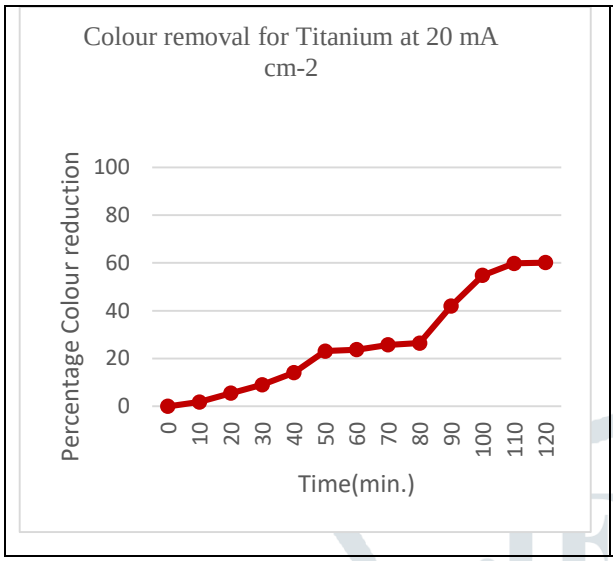


Fig. 6 colour reduction 60.18%

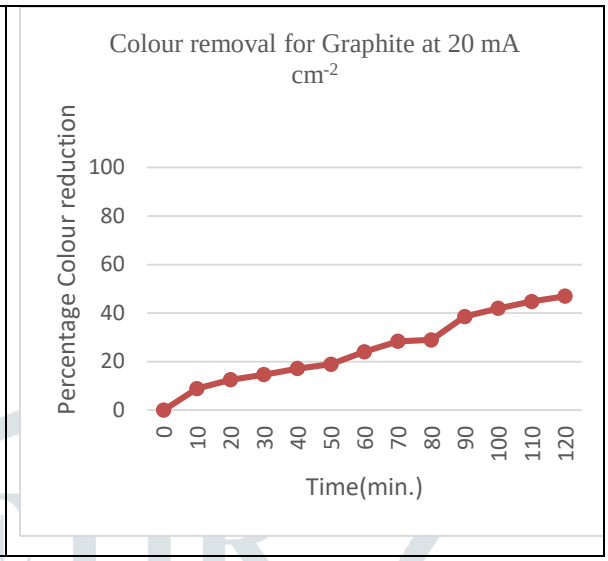


Fig. 7 colour reduction 46.96%

3.1.4 Electrochemical reduction of acid black 210 at current density of 25 mA cm^{-2}

A further increase in current density from 20 to 25 mA cm^{-2} lead to decrease in colour removal efficiency of both plates. For Titanium cathode percentage decolourization was 46.7% and in the case of graphite percentage decolourization was 41.8%.

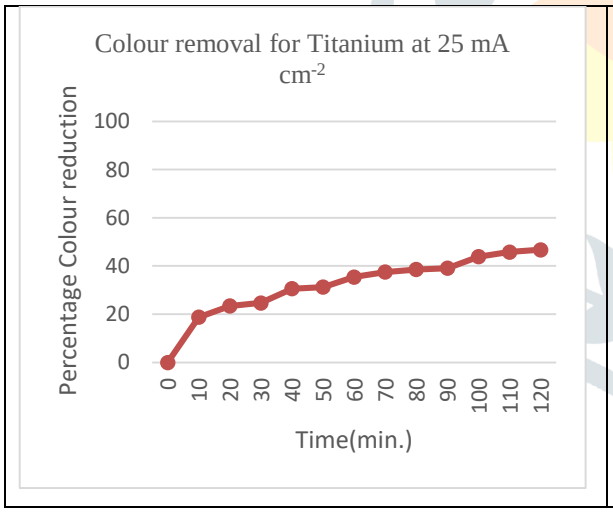


Fig. 8 colour reduction 46.71%

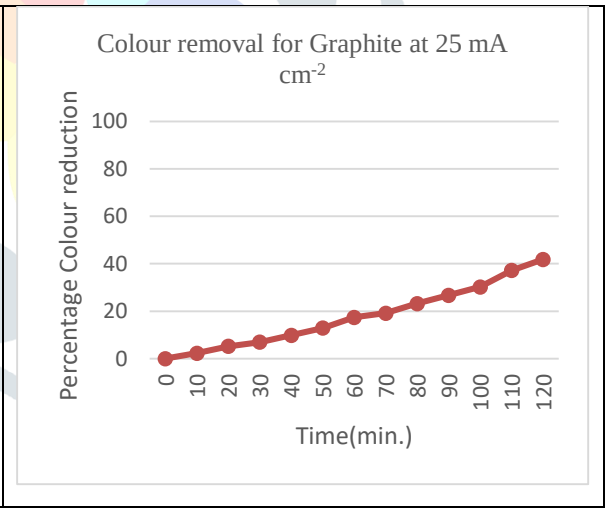


Fig. 9 colour reduction 47.86%

3.1.5 Electrochemical reduction of acid black 210 at current density of 30 mA cm^{-2}

When the current density increased to 30 mA cm^{-2} its lead to hydrogen evolution reaction, when the generation rate of hydrogen was greater than the amount of pollutants adsorbs on the surface of the cathode. At the same time evolved hydrogen formed a layer on the surface of the cathode which covered the active sites of electrode so overall efficiency was decreased. Here for Titanium cathode percentage decolourization was 46.11% and in the case of graphite percentage decolourization was 38.75%.

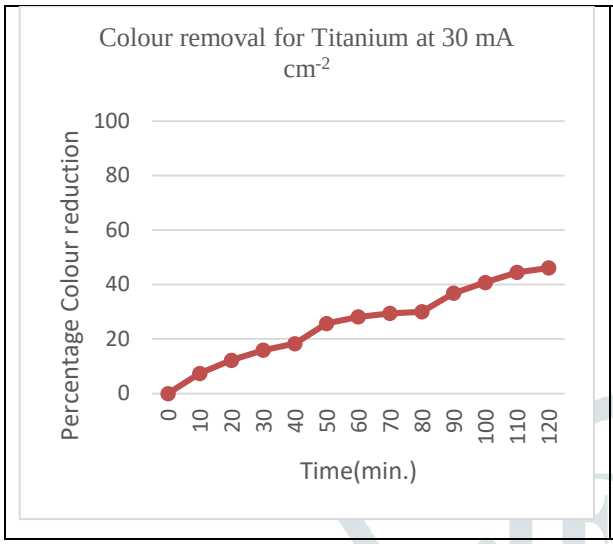


Fig. 10 colour reduction 46.11 %

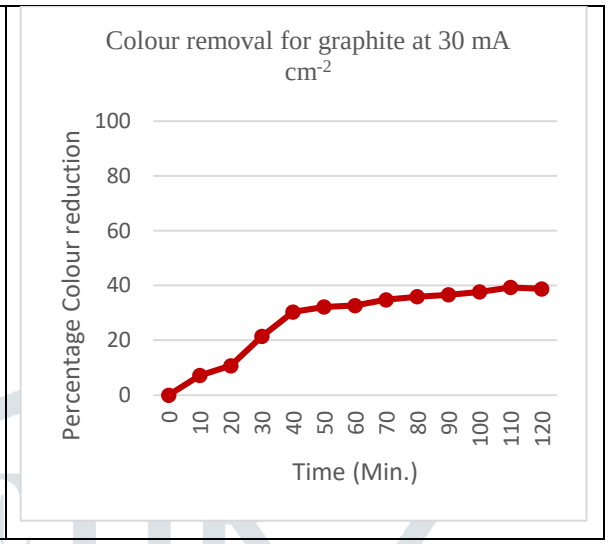


Fig. 11 colour reduction 38.75%

All the final results for synthetic waste in percentage decolourization after 120 min. are given in below table.

Sr no.	Current density (mA cm^{-2})	Titanium (percentage decolourization)	Graphite (percentage decolourization)
1	10	46	62.33
2	15	60	63
3	20	60.1	47
4	25	46.7	41.8
5	30	46.11	38.75

3.2 FOR TREATMENT OF LIVE WASTE FOLLOWING RESULTS ARE OBTAINED

Same concept and mechanism can be applied for the live waste also. Here in cathode compartment 15 ml of dye was added and other 285 ml electrolyte (0.05M Na_2So_4) were added together.as a material of cathode both plate graphite and titanium were tested. From the experiment, it is clear that if concentration of electrolyte is high then it increases the electric current densities in the solution and, for this reason, high concentrations of inert electrolyte should increase the electrode reaction rate.

When graphite was used as the cathode, optimum colour removal was 70% at current density of 30 mA cm^{-2} after 120 minutes. When Ti was used as the cathode, optimum colour removal was 56.28% at current density of 35 mA cm^{-2} after 120 minutes

3.2.1 Electrochemical reduction of acid black 210 at current density of 20 mA cm^{-2}

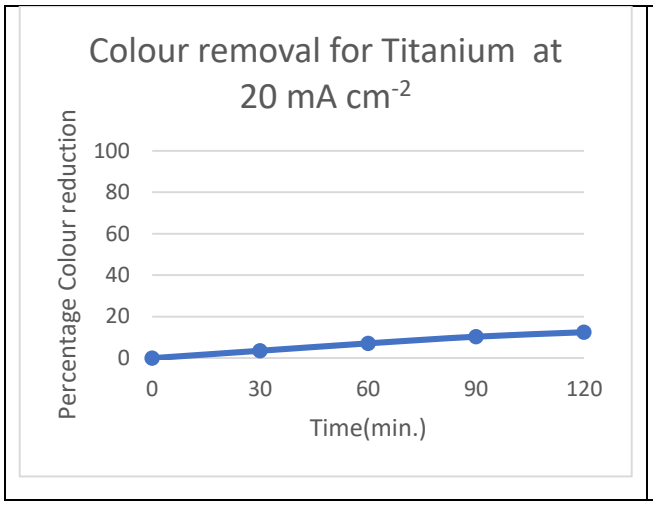


Fig. 12 colour reduction 12.5 %

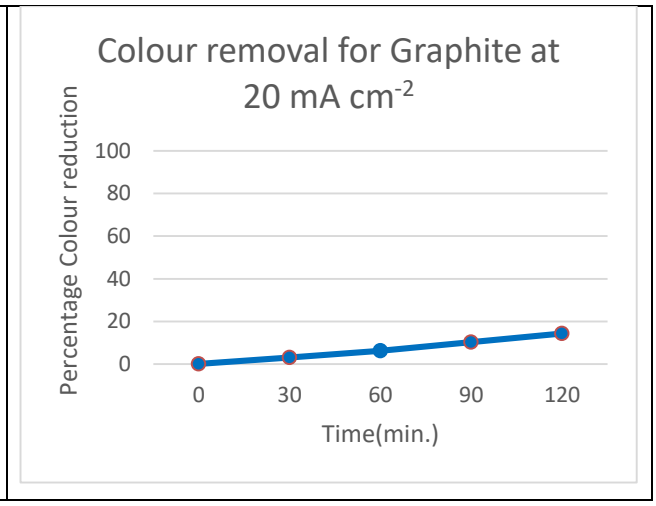


Fig. 13 colour reduction 14.34 %

3.2.2 Electrochemical reduction of acid black 210 at current density of 25 mA cm^{-2}

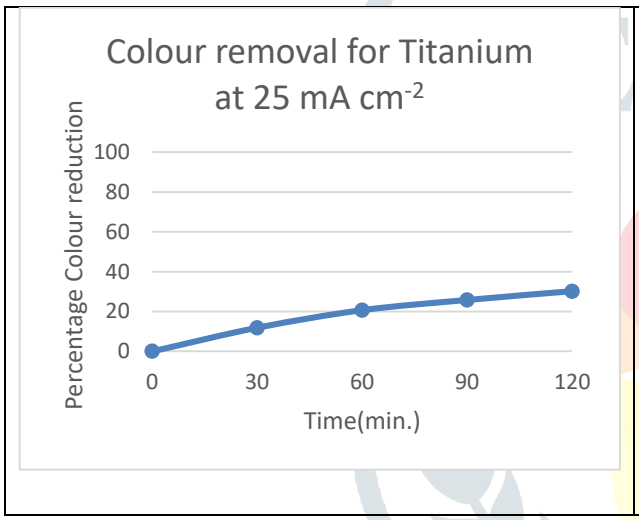


Fig. 14 colour reduction 30.16 %

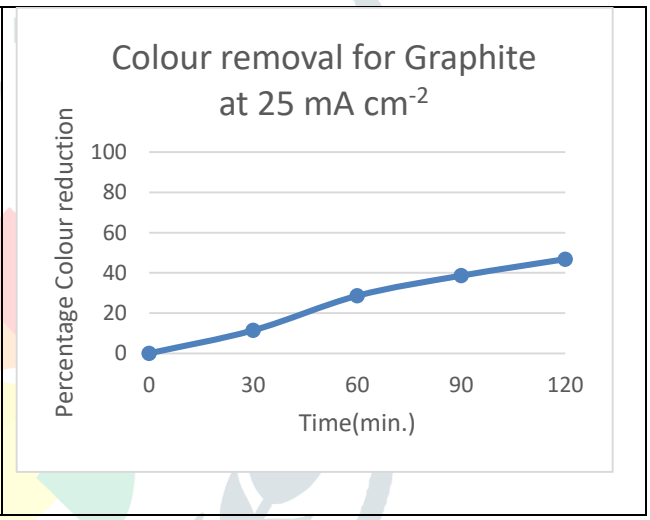


Fig. 15 colour reduction 46.78%

3.2.3 Electrochemical reduction of acid black 210 at current density of 30 mA cm^{-2}

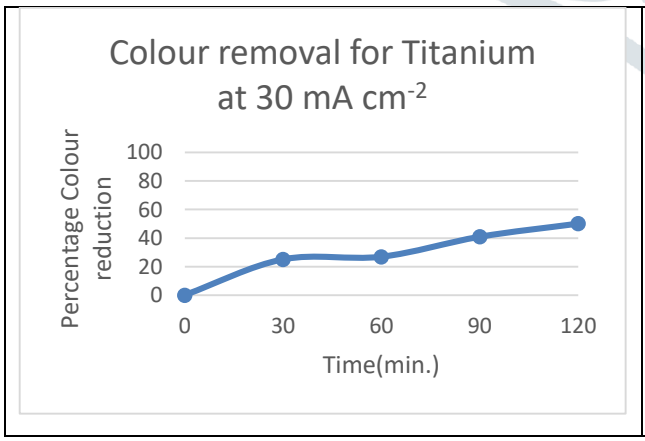


Fig. 16 colour reduction 50.18 %

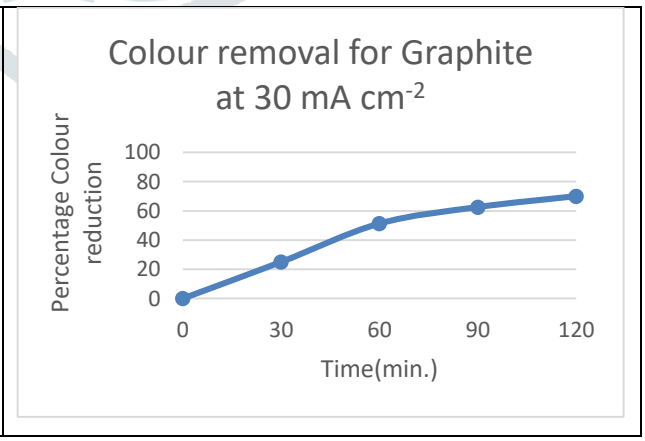


Fig. 17 colour reduction 70 %

3.2.4 Electrochemical reduction of acid black 210 at current density of 35 mA cm^{-2}

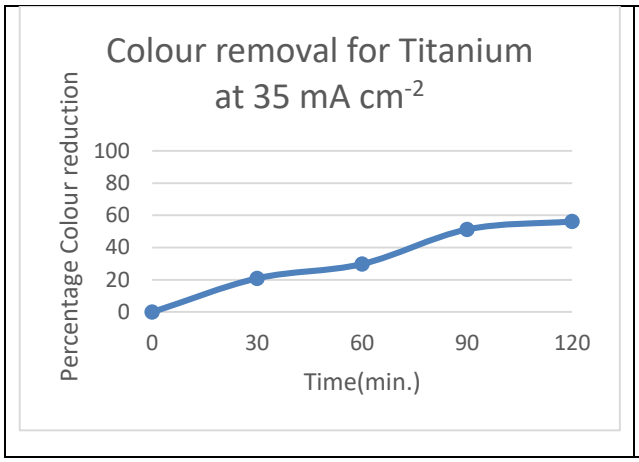


Fig. 18 colour reduction 56.28%

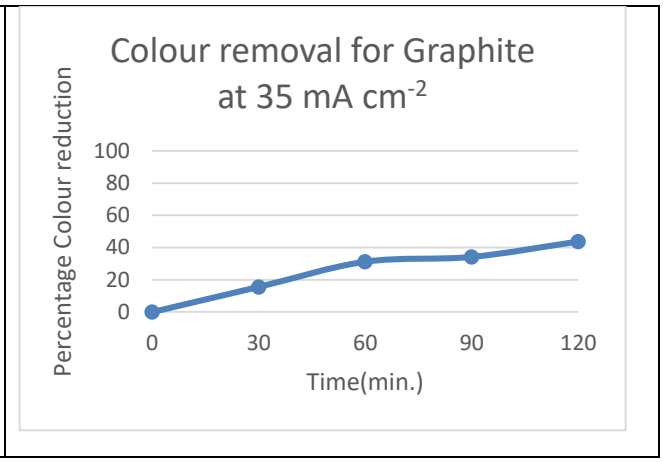


Fig. 19 colour reduction 43.75 %

3.2.5 Electrochemical reduction of acid black 210 at current density of 40 mA cm^{-2}

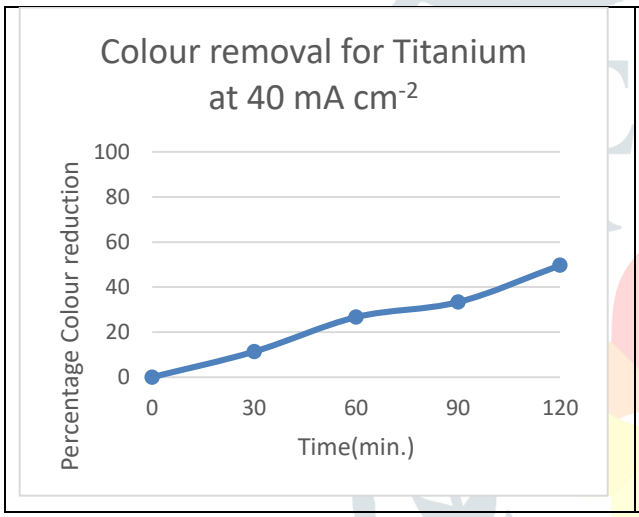


Fig. 20 colour reduction 49.66 %

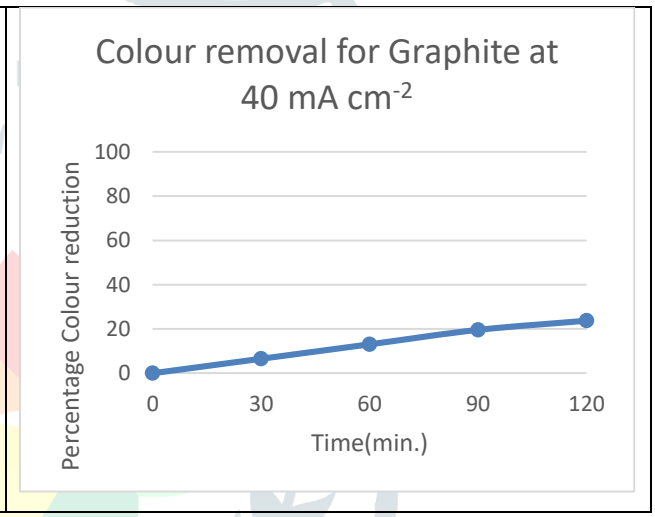


Fig. 21colour reduction 23.69 %

All the final results for live waste in percentage decolourization after 120 min. are given in below table.

Sr no.	Current density (mA cm^{-2})	Titanium (percentage decolourization)	Graphite (percentage decolourization)
1	20	12.5	14.34
2	25	30.16	46.78
3	30	50.18	70
4	35	46.7	43.75
5	40	49.66	23.69

4 CONCLUSION

Acid Black 210 could be successfully decolourizes in the cathode compartment with the help of both cathode material Graphite and Titanium. We can say that for synthetic dye, from all these current densities, optimum colour reduction obtains at 15mA cm^{-2}. When Titanium was used as a cathode percentage decolourization was 60% and in the case of graphite percentage decolourization was 63%. These electrodes were used 8-10 times at the same efficiency after that it need to be clean. It was noted that as current density increases to a certain level (Here 15 mA cm^{-2}) then removal efficiency also increased, but further increase in current density lead to decrease in removal efficiency. For the live waste, when graphite was used as the cathode, optimum colour removal was 70% at current density of 30 mA cm^{-2} after 120 minutes. When Ti was used as the cathode, optimum colour removal was 56.28% at current density of 35 mA cm^{-2} after 120 minutes.

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