Treatment of Textile Wastewater by Electro-Fenton Process Using Iron and Graphite Electrode

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Abstract **- The Electro-Fenton (EF) process is gaining momentum because of its applicability in various ranges of wastewater treatment, especially in the treatment of textile wastewater. The textile wastewater is characterised by heavy COD and colour content that the conventional treatment methods cannot treat satisfactorily and the EF method is seen to be the most efficient amongst the upcoming methods. The process is carried out by varying the pH for each run, along with simultaneously varying the H_2O_2/Fe^{2+} dosages. Two different electrodes iron and graphite are used, and their efficiencies are compared. At the optimum experimental condition, i.e, with pH as 3 and at 120 minutes, iron electrodes showed the highest COD and colour removal efficiencies of 95% and 100% respectively. The highest COD and colour removal efficiencies were seen to be 95.3% and 99.7% respectively for H_2O_2/Fe^{2+} of optimal conditions, with the provision of iron electrodes itself. The graphite electrode showed COD and colour removal of 84.8% and 97.9% respectively at a pH range of 3 at 120 minutes. Though both the electrodes have given satisfactory results, iron electrodes are considered a better alternative due to its efficiency, cost, ease of availability and maintenance.**

INTRODUCTION

Textile industry wastewater is a very diverse sector having a wide range of raw materials, processes, and methods. They make use of lot of chemicals in the form of dyes, acids, alkalis etc. The processes like sizing, de-sizing, scouring, bleaching, dyeing, printing, finishing require large amount of water along with the chemicals and thus the generation of wastewater is also high. Generally, wastewater from textile industry is characterised by large amount of COD and BOD along with colour. The wastewater sample was collected from one of the textile industry MN Tex-Exporter located in Karur, Tamil Nadu. This company has a turnover of about 2-5 crores and has created a niche in the global market. In order to reduce the pollution caused, advanced treatment method is one of the promising technologies to minimise as it is not much time consuming and the removal efficiency is also high when compared to other treatment processes.

ADVANCED OXIDATION PROCESS

This process was first proposed in 1980's used for the treatment of drinking water and lately it has been used for the treatment of wastewater as well. The general principle involved in this method is the continuous generation of hydroxyl and sulphate radicals to remove all the pollutants and other contaminants.

ELECTRO-FENTON PROCESS

In order to overcome the previously mentioned issues Electrochemical Advanced Oxidation Process (EAOP) got more consideration for the remediation of water. Among EAOP's, Electro-Fenton process is the most prevalent procedure. This process is increasingly economical, environmental friendly in treatment and removal of the organic pollutants compared to conventional technologies. In this process the sludge production is low, Onsight production of H_2O_2 minimising the transportation, storage and handling risks, degradation of large amount of organic pollutants due to continuous generation of ferrous ion and also used as effective pre-treatment for biological processes are some of its advantages over Fenton process and thus it proves to be more efficient in the treatment processes.

MECHANISM OF ELECTRO-FENTON PROCESS

The typical mechanism of the Electro-Fenton process is illustrated as in the figure 1 given below. This process basically includes both electrochemical and Fenton methods which are equally powerful and effective method for the treatment process. Compared to conventional Fenton's reagent more attention have been laid on Electro-Fenton processes as it is easy to treat, environmentally friendly, reacts well with the organics and doesn't produce toxic chemicals and secondary pollutants during oxidation. The oxidation of the OH is the main mechanism of this process which serves as one of the most powerful oxidizing agent.

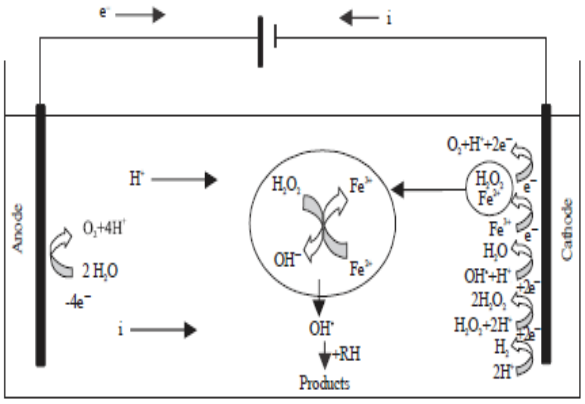


Fig 1: Schematic representation of reaction mechanism of Electro-Fenton process

OPERATING PARAMETERS

- pH: It poses a significant impact on the EF process as it controls the variation in Iron and hydroxyl radicals generated. Thus, an optimum pH range of 3-3.5 is maintained. If the pH range is lesser than 2 and greater than 4 degradation of wastes occurs.
- Temperature: It is inversely proportional to the removal efficiency. Thus, an optimum temperature should be maintained where variations may affect the removal efficiency.
- Fe^{2+} concentration: It is also inversely proportional to the removal efficiency.
- H_2O_2 concentration: It is directly proportional to the COD and TOC removal efficiency in the EF process.
- Distance between the electrodes: The distance maintained between the 2 electrodes is very much necessary in order to avoid short circuits and it is also directly proportional to the removal efficiency in the EF process.

MATERIALS AND METHODOLOGY

Experimental Strategy

Wastewater collected was examined for different physical, chemical parameters and it was obtained that the wastewater test was portrayed by high COD and colour. Electro-Fenton test was carried out in laboratories utilizing a magnetic stirrer with operating parameters like pH, voltages, hydrogen dose of hydrogen peroxide and by utilizing iron electrodes so as to acquire the most removal efficiency and all these distinctive parameters were optimised.

Experimental Setup

The experiment was carried out in a 2L reactor with a solution volume of 1L. For Electro-Fenton reagent ferrous sulphate heptahydrate was utilized as a source of iron and 30% of w/v hydrogen peroxide was utilized. While performing the experiment the wastewater was brought under room temperature and iron electrodes were added to it followed by the addition of hydrogen peroxide. The reaction mixture was agitated for known interval of time and in every analysis the time of addition of Hydrogen peroxide is known as the beginning time of the Fenton's reaction. The agitation speed was maintained at 300-350 RPM. Fenton regent (H_2O_2/Fe^{2+}) dosage used was 400/400 mg/L, 500/400 mg/L and 600/400 mg/L as described in the table below to check the efficiency of the COD evacuation. Further the pH studies were carried out by shifting pH from 2, 3 and 4 with 0.1N HCL and the reaction time optimization was done utilizing the optimized Fenton dosage and pH.

Electro-Fenton Experiment

The preliminary study was led on having a reactor size of 2L and for every analysis the reactor was filled with 1L of wastewater. The two iron electrodes were submerged into the solution indicating cathode and anode. The area of iron electrode is 10.5*5cm height and the spacing given between the electrodes is 2cm. A direct electrical source was connected to the iron electrode at 4, 6 and 8V and the experiment was carried out for 120min of time drawing the sample at every 15min of the run and analysed for colour and COD separately. The Fe^{2+} concentration was kept

steady of 400 mg/L and H_2O_2 was added to the reactor by changing various dosages of 400, 500 and 600 mg/L. Further pH studies were carried out by shifting pH to 2, 3 and 4 with 0.1N HCL.

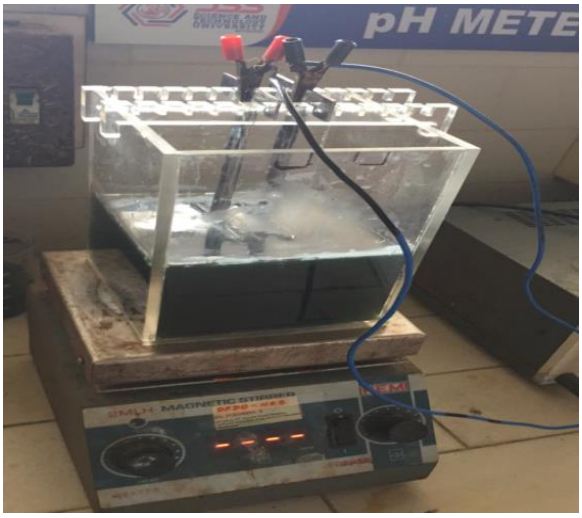


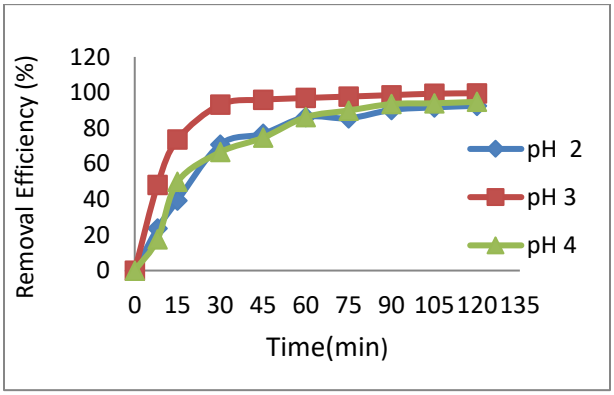
Fig 2. Experimental setup

Kinetic Studies

To analyse the kinetics of COD removal efficiency, experiments were carried out for different parameters. The study time versus COD concentration from the treated wastewater at optimum condition were considered to be zero order kinetics, time versus natural logarithm of COD concentration to be first order kinetics and time versus 1 in COD concentration to be second order kinetics. The graph with highest value of R^2 was considered as the mechanism of kinetics of Electro-Fenton process.

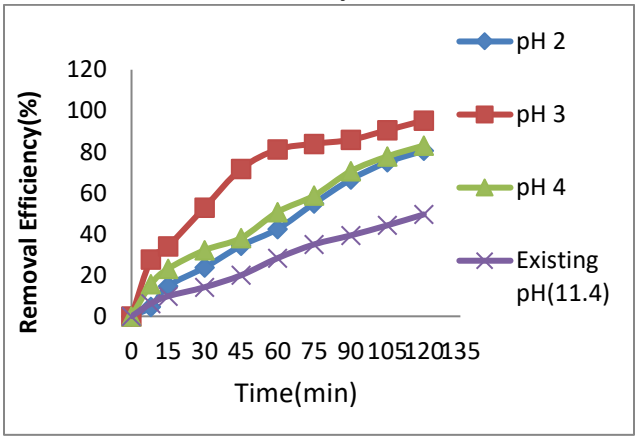
RESULT AND DISCUSSION

1. Electro-Fenton process using Iron Electrodes.
1. Experiment on color and COD removal for varying pH condition



% color removal vs time for varying pH, (H_2O_2-900mg/L, Fe^{2+} - 400mg/L, current-5V)

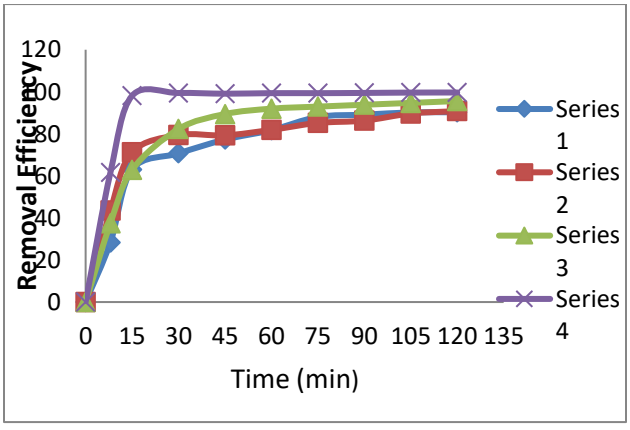
It can be observed that the highest color removal efficiency obtained was 100% for pH 3 at 105 and 120 minutes but at 45 minutes the efficiency was found to be 96% and it has risen minutely afterwards,



% COD removal vs time for varying pH(H_2O_2-900mg/L, Fe^{2+} - 400mg/L, current-5V)

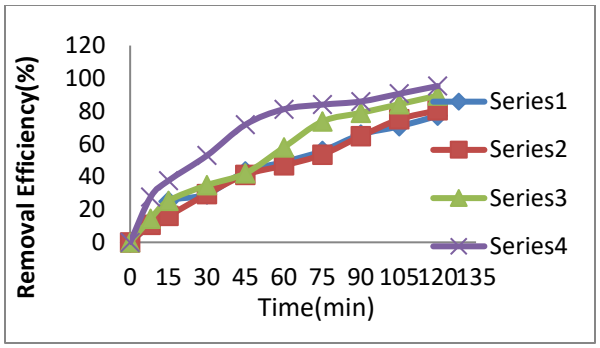
It can be observed that the highest COD removal efficiency obtained was 95% for pH 3 at 120 minutes. The pH 2 and pH 4 showed a removal efficiency of 80% and 83% but the existing pH showed the least efficiency of 49%.

2. Experiment on color and COD removal for varying H2O2 and Fe^{2+} concentration



% of color removal vs time for varying H_2O_2 and Fe^{2+} concentration (pH 3, current 5V)

The maximum color removal efficiency was 99.7% for series 4 with the H_2O_2/ Fe^{2+} dosage of 900 mgL^{-1}/400 $mgL^{-1}$and the subsequent removal efficienciesfor series 1, 2 and 3 were 90.2%, 90.8% and 95.6% respectively.

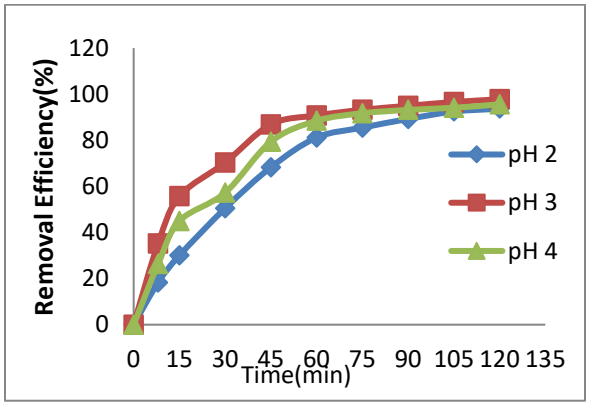


% of COD removal vs time for varying H_2O_2 and Fe^{2+} concentration(pH 3, current 5V)

The highest COD removal efficiency was 95.3% in series 4 for H_2O_2/ Fe^{2+} dosage of 900 mgL^{-1}/400 mgL^{-1} andthe subsequent removal efficiencies for series 1, 2 and 3 were 77.1%, 80.5% and 89.4%

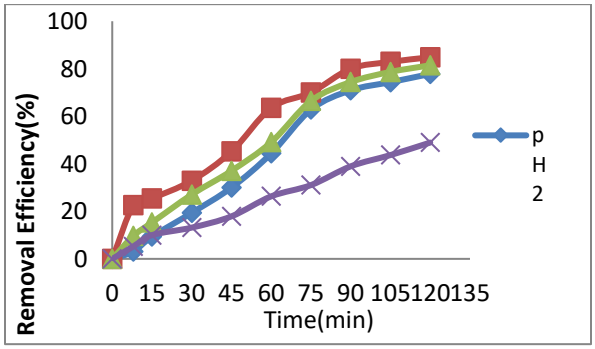
2. Electro-Fenton process using Graphite

1. Electrodes Experiment on color and COD removal for varying pH condition



% of color removal vs time for varying pH(H_2O_2-900mg/L, Fe^{2+} - 400mg/L, current-5V)

Highest colour removal efficiency was 97% obtained at pH 3 and this pH range have maintained a constant and steady removal rate. A sudden increase in the efficiency can be seen at 45 minutes and followed by a gradual increase.

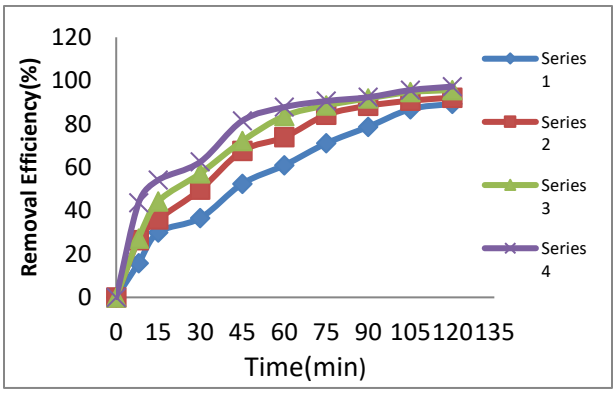


% of COD removal vs time for varying pH(H_2O_2-900mg/L, Fe^{2+} - 400mg/L, current-5V)

The highest COD removal efficiency was 84% obtained at a pH of 3 at 120 minutes. At pH 3 the removal efficiency increases steadily and the drastic improvement in the efficiency can be seen at 90 minutes with 80% followed by a consistent increase.

2. Experiment on color and COD removal for varying H_2O_2 and Fe^{2+} concentration

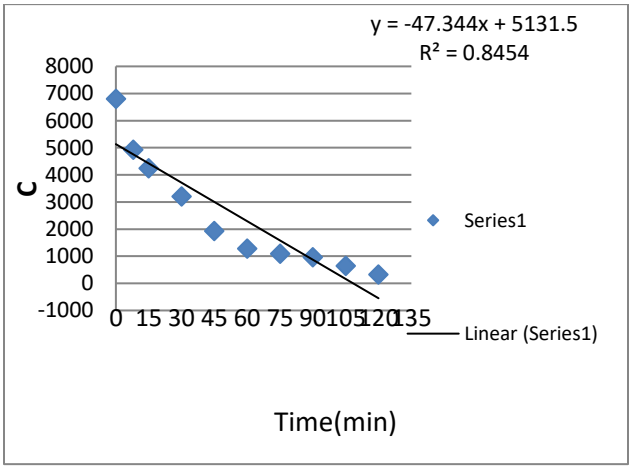
The maximum colour removal efficiency was seen to be 97.2% in series 4, with the optimalH_2O_2/ Fe^{2+} dosage of 900 mgL^{-1}/400 mgL^{-1} and the corresponding efficiencies for series 1, 2 and 3 were observed to be 89.3%, 92.1% and 95.6%



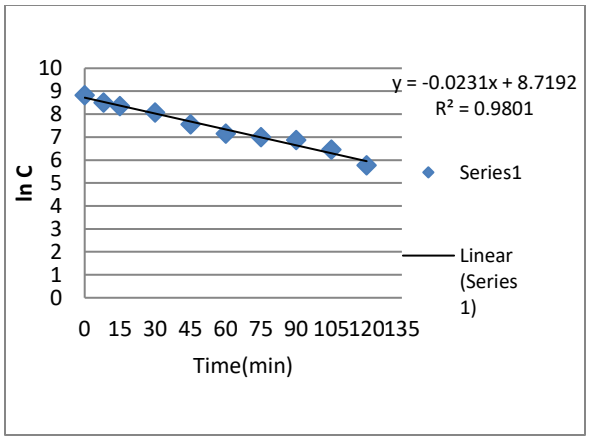
% of color removal vs time for varying H_2O_2 and Fe^{2+} concentration (pH 3, current 5V)

Kinetic Analysis for the Obtained Results

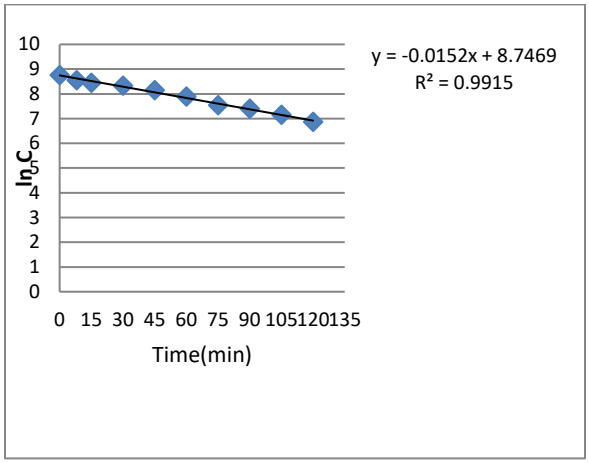
1. Zero order reaction for COD removal for Iron Electrode.



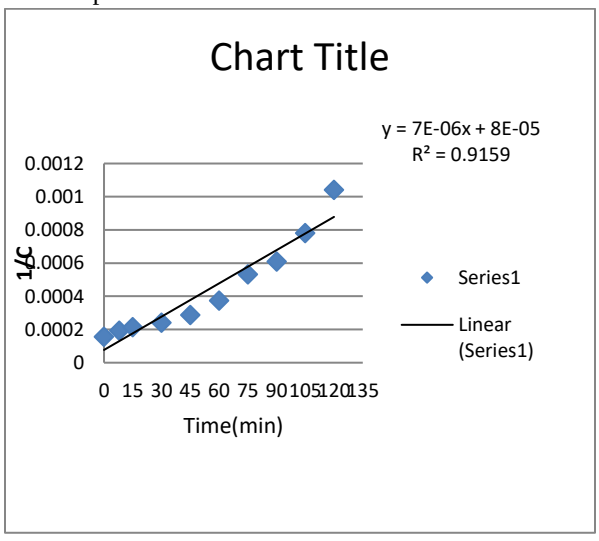
2. First order reaction for COD removal for Iron Electrode



3. First order reaction for COD removal for Graphite Electrode.



4. Second order reaction for COD removal for Graphite Electrode.



CONCLUSION

The textile wastewater is characterised by high COD of 6000-9000 and very dark nature of purple colour. For iron electrode at an optimal pH of 3 and when the dosage of H_2O_2/ Fe^{2+} given were 900 mgL^{-1}/400 mgL^{-1} the removal efficiency of COD and colour were 95.3% and 99.6% where for the graphite electrode with same optimal conditions as that of the iron electrode the removal efficiency of COD and colour are 85% and 97.7% respectively. On this comparison the removal efficiency of iron electrode is slightly higher than that of the graphite electrode whereas the main difference is that in iron electrode there is a sudden removal at a particular point of time between 40 to 60 min whereas in graphite electrode the removal process occurs gradually. At the end the kinetic studies done revealed that the process of COD removal efficiency in textile industry wastewater takes place through first order kinetics for both graphite and iron electrodes.