

Treatability Studies for Hospital wastewater using Advanced Oxidation process

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ABSTRACT: The present study deals with the treatment of Hospital wastewater using Advanced Oxidation Process. The Hospital wastewater used for the present study is characterized by high COD with relatively low BOD₅/COD ratio 0.25-0.29. The effect of operating conditions for Fenton and Electro Fenton process includes H₂O₂/Fe²⁺, Contact Time, H₂O₂ dosage and pH on the efficiency of COD removal was investigated. From the set of several experiments conducted on Fenton studies, the result showed reduction in COD removal efficiency of 80% for 0.4g Fe²⁺ + 0.8ml H₂O₂ Fenton dosage at 50 RPM and 120 minutes reaction time. The improvement in BOD₅/COD (0.25 to 0.41) was observed at the end of 120 minutes which clearly indicates that treated effluent is biodegradable with seeding. Electro Fenton process showed reduction in COD removal efficiency of 88% for 1 ml H₂O₂ dose at 120 minutes reaction time. The improvement in BOD₅/COD (0.25 to 0.52) was observed at the end of 120 minutes which clearly indicates that treated effluent is easily biodegradable. The kinetic study revealed that the rate of COD reduction followed a first order reaction for both Fenton and Electro Fenton process.

KEYWORDS: Fenton, Hospital wastewater, Electro Fenton, organic materials.

I. INTRODUCTION

Waste in general is any substance (solid, liquid, or gas) that has no direct use and is discarded permanently. According to Department of Environment (DOE) 2009; hospitals, clinics, pharmacies and nursing homes are referred as health care establishment and care has to take to avoid hazardous wastes let into the environment. Hospitals consume an important volume of water a day. Hospitals consume water for domestic applications on an average of 400-1200 litre per bed per day. In hospitals, the water consumed in different units such as clinics, operation rooms, laundry units, laboratories, kitchen, health services and administrative units which later converted as wastewater generation. Both liquid and solid wastes are generated in hospitals and it is difficult to manage these kinds of wastes in the premises. Hospitals generate on an average 750 litres of wastewater per bed per day. These effluents are loaded with number of toxic chemicals, radioactive elements, pathogenic organisms and pharmaceutical partially metabolised elements and antibiotics. Hence it is necessary to take precautionary measures through proper treatment technology by applying safe disposal methods (Mohankumar and Kottaiveeran, 2011).

The treatment of hospital wastewater is one of the main prerequisites for reducing harmful impact on the environment (Alrhoun, 2014). Efforts have been made in various parts of world to develop an efficient and economic process for treating the hospital wastewater. Many numbers of new technologies are developing for treating hospital wastewater in all over the world to have a greater removal efficiency of pollutants. There are large number of techniques and technologies available for treatment of wastewater. Treatment of hospital wastewater can be carried out by various physical, chemical and biological methods. Removal of various organic and inorganic substances can be removed by advanced treatment methods such as by addition of Fenton reagents to wastewater for their higher removal efficiency. If the wastewater is characterised by high concentration of COD and relatively low concentration of BOD/COD ratio can easily be treated by Advanced Oxidation Process. The use of AOPs can be widely used for high strength wastewater. This method can be coupled with other physico-chemical treatment for higher removal of pollutants (Kulkarni and Kherde, 2015). Advanced oxidation methods are very effective alternative for treatment of wastewater. Advanced Oxidation process (AOP) is found to be very effective for the treatment of Hospital wastewater.

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Various oxidizing agent like hydrogen peroxide, Fenton reagents and TiO_2 catalyst can be used for effective treatment of wastewater (Umadevi, 2012). Fenton treatment is used for removing COD and enhancement of biodegradability of wastewater. Electro Fenton (EF) is powerful for degrading most organic compounds including toxic and non-biodegradable ones. Due to the increasing species and amount of toxic and bio refractory organic pollutants in wastewater, great attention has been paid on advanced oxidation processes (Sharma et al., 2011).

II. MATERIALS AND METHODOLOGY

1. Fenton oxidation experiments

Fenton experiments were carried out in the laboratory in Jar test apparatus. For Fenton reagent, ferrous sulphate heptahydrate was used as a source of Iron (in the crystalline form) and 30 % w/v hydrogen peroxide was used. All Fenton experiments were carried out with a mixing speed of 50 RPM. Preliminary Fenton studies were carried with a Fenton dosage $0.1\text{g Fe}^{2+} + 0.2\text{ml H}_2\text{O}_2$ and then the Fenton dosage was varied till $0.5\text{g Fe}^{2+} + 1\text{ml H}_2\text{O}_2$ to check the efficiency of the COD removal. Several experiments were done in this regard to find optimized Fenton dosage. Further pH studies were carried by varying pH from 3 to 5, where 0.1N HCL was used for pH adjustments.

2. Electro Fenton oxidation experiments

The preliminary study was conducted on Electro coagulation (EC) for 120 minutes reaction time and samples were drawn for known intervals of time and analyzed for parameters in considerations. By the results obtained from EC, the performance of Electro Fenton (EF) process for treating hospital wastewater was evaluated in lab scale. Two Iron electrodes were immersed in a solution in the beaker which acts as cathode and anode respectively. The size of the iron electrodes are 5cm diameter and 5cm height and the spacing of electrodes was 3cm. A direct electrical current was applied to the iron electrodes at 5V. The Hydrogen peroxide was added to the reactor after 10min of start of the reaction.

III. RESULTS AND DISCUSSIONS

Hospital wastewater was collected from JSS hospital, Mysuru in Operation Theatres (OT's) and Laundry unit. The OT's wastewater includes instruments and floor cleaning wash water. It was found that the hospital wastewater was characterized by high COD 8000-8800 mg/L, BOD 2000-2500 mg/L, Phosphate 13-14.5 mg/L, Nitrate 19-22.5 mg/L, Chloride 125-135 mg/L and Sulphate 19.3-21 mg/L.

Fenton Experiments for Hospital wastewater treatment

Experiments for different Fenton dosages

To investigate the optimum $\text{H}_2\text{O}_2/\text{Fe}^{2+}$, the several experiments were conducted for varying Fenton dosages from $0.1\text{g Fe}^{2+} + 0.2\text{ml H}_2\text{O}_2$ to $0.5\text{g Fe}^{2+} + 1\text{ml H}_2\text{O}_2$ for existing wastewater pH 7.95, 50 RPM and 2 hours reaction time were shown in Figure 1. It clearly seen that the better results of COD removal among the other mentioned dosages are obtained for $0.4\text{g Fe}^{2+} + 0.8\text{ml H}_2\text{O}_2$ and this dosage was considered as optimum dosage with COD removal efficiency of 80% was achieved.

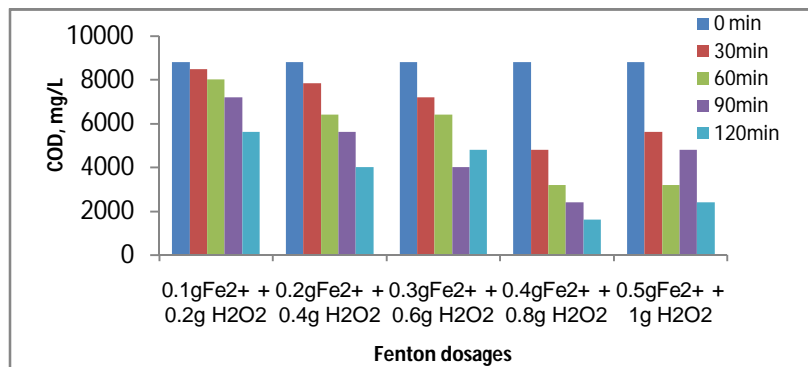


Fig 1 COD concentration v/s different Fenton dosages

Contact Time studies

In order to study the effect of contact time/ Reaction Time for treating health care wastewater using Fenton method, the optimum Fenton dose 0.4g Fe²⁺ + 0.8ml H₂O₂ was repeated for the study. It was observed that nearly 50% of COD removal was found during 60 minutes of reaction time and further 30% additional COD removal takes place at the end of reaction time, resulting in 80% overall COD removal for hospital wastewater. The residual hydrogen peroxide (Weight %) were found to be 1.79 conducted by Permanganate method.

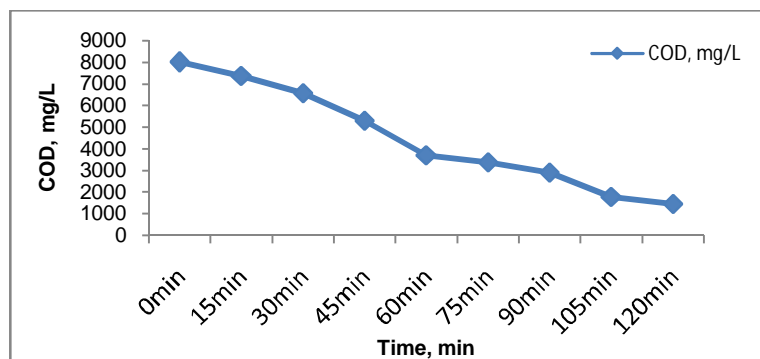


Fig 2 COD concentration v/s Contact Time for Existing pH

pH studies

The effect of initial pH on COD removal efficiencies was studied for different range of pH from 3 to 5. Figure 3 represents COD concentration v/s Contact Time for varying pH. The pH of raw wastewater was lowered to 3, 4 and 5 using 0.1 N HCl followed by addition of 0.4g Fe²⁺ + 0.8ml H₂O₂ to the Jar test for reaction time of 2 hours and the resulting supernatant was analyzed for parameters in consideration. The most effective reaction was observed at pH 3 with COD removal efficiency of 88 % was achieved. It was observed; nearly 50% of COD removal was found during 45 minutes of reaction time and further 38% additional COD removal takes place at the end of reaction time, resulting in overall 88% COD removal. The residual hydrogen peroxide (Weight %) were found to be 2.68 conducted by Permanganate method.

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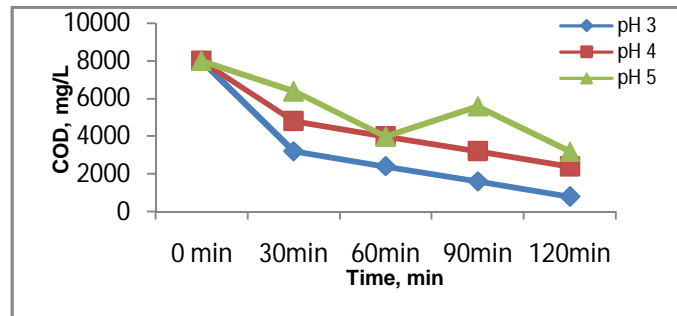


Fig 3 COD concentration v/s Contact Time for varying pH

Electro Fenton oxidation experiments

The batch experimental setup for treatment of Hospital wastewater by preliminary study on Electro coagulation (EC) was conducted. By the results obtained from EC, the performance of Electro Fenton process for treating hospital wastewater was evaluated. To examine the effect of initial pH and contact time, the study was conducted to determine optimum electrolysis duration for existing hospital wastewater pH. Effect of operating time on COD removal was shown in Figure 4, indicates that an increase in electrolysis time from 0 to 120 minutes yielded an increase in the removal efficiencies of COD. It is seen that, the rate of COD reduction was gradual up to 75 minutes and later on there was slight reduction in COD removal was observed. The maximum COD reduction of 64% was achieved at 120 minutes electrolysis time.

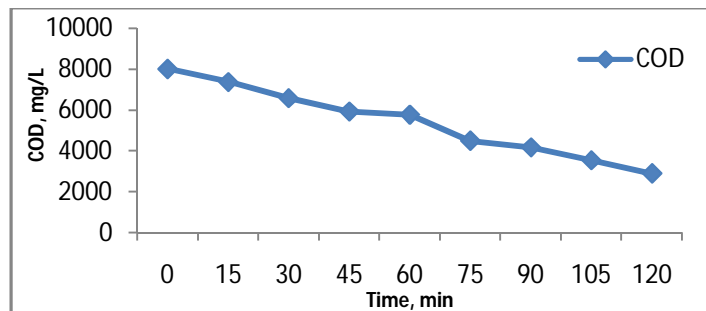


Fig 4 COD concentration v/s Electrolysis Time for Existing pH

The experiments were performed by maintaining different distances of 2-4 cm between the electrodes with 500 RPM and 120 min electrolysis time. The effect of distance between electrodes for the COD concentration as a function of time is presented in Figure 5. By increasing the distance between the electrodes from 2 to 3 cm, the efficiency of COD removal was increased from 53% to 64%. Later by increasing the distance from 2 to 4 cm, the efficiency of COD removal was decreased to 40%. It can be noticed that the COD removal efficiency decreases with an increase in the spacing between the electrodes from 2 cm to 4 cm. This is due to the fact that an increase in the electrode spacing decreases the electrostatic effects resulting in a slower movement of the generated ions. Therefore, overall study on ECC depicts that, at initial pH 7.9, voltage 5V, electrode distance 3 cm and 120 minutes electrolysis time, the removal efficiency of COD was observed to be 64% respectively.

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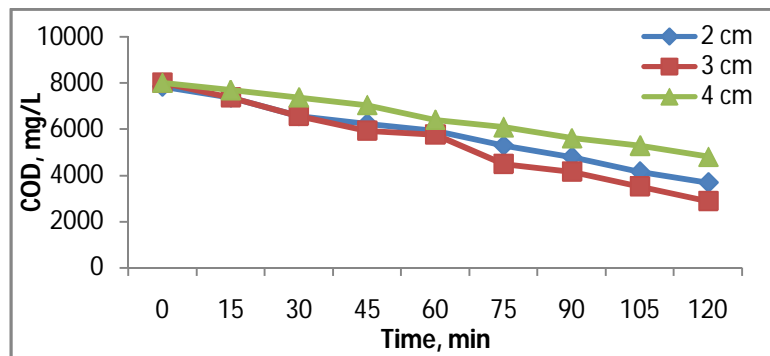


Fig 5 COD concentration v/s Electrolysis Time for varying electrode distance

Electro Fenton Experiments

Experiments for different Hydrogen peroxide dosage

Dosage of Hydrogen peroxide (H_2O_2) is an important parameter for COD removal in the Electro Fenton method. In this study the performance of Electro Fenton process on COD removal from the hospital wastewater were investigated. Optimum dose has been studied by varying different dose of 0.8 ml, 1 ml, 2 ml and 3 ml H_2O_2 for 1 L wastewater sample. As shown in Figure 6, different doses of H_2O_2 have been studied for maximum COD removal for hospital wastewater by keeping Iron electrodes distance 3 cm, 500 RPM, at existing wastewater pH and 120 minutes reaction time.

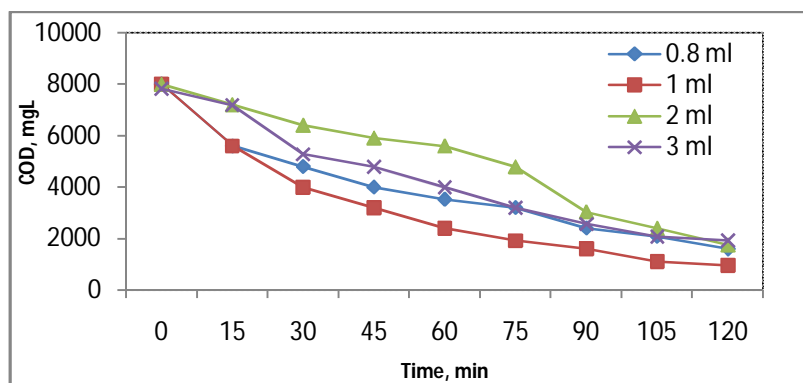


Fig 6 COD concentration v/s Contact Time for varying H₂O₂ dosage

As shown in Figure 6, the result shows that nearly 50% of COD removal was found at 30 minutes reaction time, furthermore there was additional COD removal of 38% was obtained at the end of reaction time attaining 88% COD removal efficiency for 1 ml H_2O_2 dose, when compared to other doses such as 0.8 ml, 2 ml and 3 ml. As stated above, higher the dose of H_2O_2 , there is a decrease in the COD removal was seen for dose of 2 ml and 3 ml, since it takes almost 75 min and 90 min to achieve for 50% efficiency. This is due to hydroxyl radical scavenging the effect of H_2O_2 and recombination of hydroxyl radical.

Contact Time studies

The effect of time was studied at the optimum 1 ml H_2O_2 dose for existing wastewater pH. It was clearly seen that from figure 7, the reaction time has a significant effect on the pollutant removal with continuous drop in COD were observed for every interval of time. When the operating time changed from 15 to 30 min, 50% COD removal were obtained,

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Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

furthermore there was a drop of 38% COD removal efficiency were found. Hence, it can be noticed that, contact time studies for hospital wastewater shows maximum COD removal efficiency of 88% at 120 minutes reaction time. At the end of experiment, residual hydrogen peroxide (weight %) were found to be 1.98 conducted by Permanganate method.

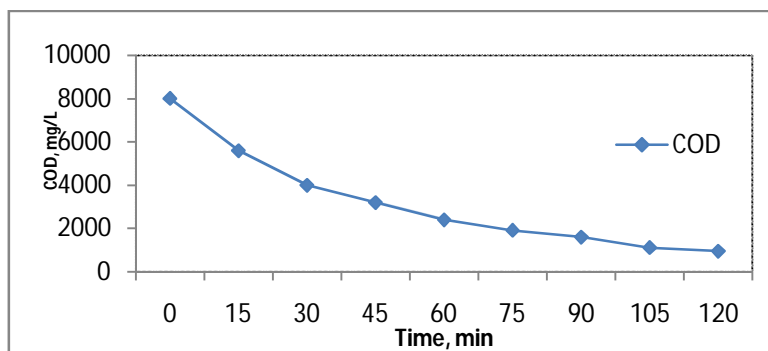


Fig 7 COD concentration v/s Contact Time for Existing pH

pH studies

pH is an important parameter for EF reactions which controls the rate of generation of hydroxyl radical. It is well known that EF processes work in acidic conditions and it has been confirmed that the optimal value of pH is 2~4 for EF studies. In all experiments, pH was reduced to 2, 3 and 4 by addition of 0.1 N HCL. To check the effect of pH on COD removal, electrolysis of the hospital wastewater was carried out at 120 minutes with constant 1 ml H₂O₂ dose.

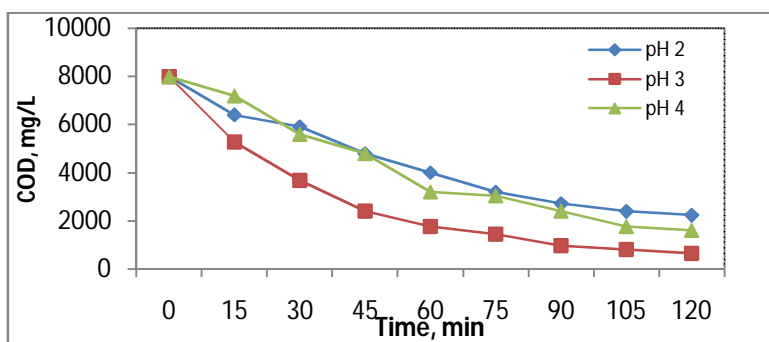


Fig 8 COD concentration v/s Contact Time for varying pH

The removal efficiencies of 72%, 92% and 80% were obtained at pH 2, 3 and 4 respectively. It has been seen that with the increase in pH to 3, the COD removal increases to 92%. But on further increasing the pH to 4, the COD removal efficiency decreases to 80% which is mainly due to the hydrolysis of iron species and instability of H₂O₂. This is due to the fact that, at low pH condition the reaction between H₂O₂ and Fe²⁺ is significantly affected, causing the reduction in hydroxyl radical production. Whereas at high pH 4, deactivation of Fe²⁺ causes the reduction of hydroxyl radical due to the formation of ferric hydroxide precipitate resulting in low COD removal efficiency. At the end of experiment, residual hydrogen peroxide (weight %) were found to be 3.05 conducted by Permanganate method.

Kinetics of Fenton and Electro Fenton Studies

The kinetic study is an important factor in order to examine the order of the reaction. It is known that the rate of many reactions is proportional to the concentration of the reactant(s) raised to small integral power. Most commonly

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Vol. 6, Issue 5, May 2017

occurring reaction rates in wastewater treatment are Zero order, first order and second order based on the raised power integer of 0, 1 and 2 respectively (Abdelaziz et al., 2015). The Fenton and Electro Fentonoxidation of the COD can be represented by the following First order reaction kinetics by:

$$\ln\left(\frac{C_0}{C_t}\right) = Kt$$

Where:

C_0 is the initial concentration, (mg/L),
 C_t is the concentration at time t , (mg/L),
 K is the rate constant, (min^{-1}) and
 t is the time, (min)

To investigate the kinetics of COD removal efficiency, experiments were carried out with different parameters effect and first order kinetics model was applied. For COD removal of hospital wastewater, comparison of kinetic simulation of Fenton and Electro Fenton reactions was studied. For the Fenton and Electro Fenton process, first order kinetics yields a good fit to the experimental data. The Electro Fenton reaction has a higher reaction rate than the Fenton reaction. Figure 9 and 10 shows the effect of Fenton dosage, pH values, H_2O_2 concentration and reaction time on the kinetics of the reaction study. Thus, study of the kinetics revealed that the processes of COD removal take place through a First order reaction for both Fenton and Electro Fenton methods.

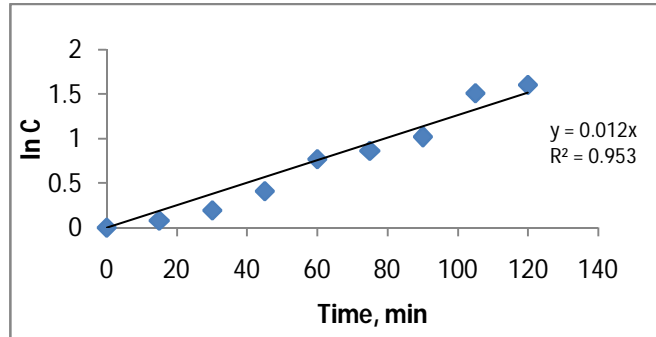


Fig 9 Effect of Optimum Fenton dosage and Existing pH on the kinetics of the reaction by Fenton process

(Initial COD concentration = 8000mg/l, Optimum Fenton dose= 0.4g Fe^{2+} + 0.8ml H_2O_2 , Existing pH= 7.56,50 RPM, Time= 120min)

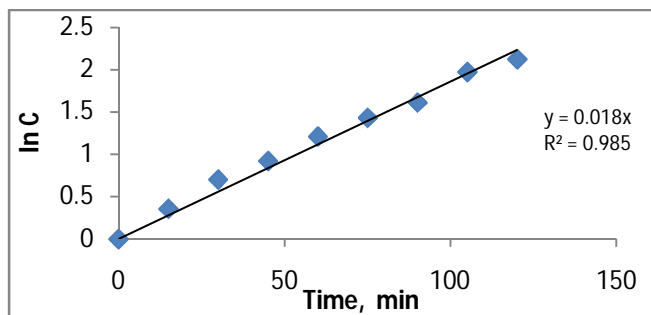


Fig 10 Effect of Optimum H_2O_2 dosage and Existing pH on the kinetics of the reaction by Electro Fenton process

(Initial COD concentration = 8000 mg/l, Optimum H_2O_2 dose= 1 ml, Existing pH= 7.9,500 RPM, Time= 120min)

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Vol. 6, Issue 5, May 2017

IV. CONCLUSION

The following are the conclusions that can be drawn from this study: Hospital wastewater is characterized by high COD and low BOD₅/COD ratio varying between 0.25-0.29 with greenish blue color. Treatability studies carried out for Fenton process showed reduction in COD from 8000 mg/L to 1600 mg/L resulting in removal efficiency of 80% for optimum Fenton dose of 0.4g Fe²⁺ + 0.8ml H₂O₂ at an existing wastewater pH 7.95. Studies carried out for Electro Fenton process showed reduction in COD from 8000 mg/L to 960 mg/L resulting in COD removal efficiency of 88% for 1 ml H₂O₂ dose at an existing wastewater pH 7.95 showed an improved BOD₅/COD ratio to 0.52. The study of kinetics on hospital wastewater revealed that the processes of COD removal efficiency takes place through a First order reaction for both Fenton and Electro Fenton methods.

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