Treatment of Pharmaceutical Wastewater by Electrocoagulation Process using Iron Electrodes

Bhushansingh Rathor[1] Dr S.R.Mise[2]
[1]M.Tech Scholar [2]Professor
[1,2]Department of Civil Engineering
[1,2]PDA College of Engineering, Kalaburagi -585102, Karnataka, India

Abstract— This work presents removal of COD (Chemical Oxygen Demand) from Pharmaceutical wastewater by Electrocoagulation (EC) process using Iron as a sacrificial electrode which is currently used for the purification of many types of water and wastewater. The effecting parameters such as applied voltage, electrolysis time and pH are studied to achieve higher removal. The performance of EC process is carried out in batch reactor. In this process, samples are taken out from the batch reactor at regular interval of 20 minutes. the experimental results also show that the COD removal is strongly influenced by the initial pH. The highest COD removal efficiency of 79.80% occurred at 1A, 16V at electrolysis time of 120 minutes with optimum pH 9 using Iron electrode. In this study, the EC process is proved effective and is capable in removing COD efficiently.

Key words: Pharmaceutical wastewater, Electrocoagulation process (EC), Iron electrode, COD, Electrolysis time, pH and Effect of Applied Voltage

I. INTRODUCTION

Water is one of the most valuable resources on planet earth. Without water life is not possible. Although this fact is widely recognized, pollution of water resources is a common occurrence. The increase in world population as well as industrial revolution has caused severe environmental pollution.

The need for high quality drinking water is one of the most challenging problems of our times, but still only little knowledge exists on the impact of these compounds on ecosystems, animals and man. Reliable access to clean and affordable water is considered one of the most basic humanitarian goals, and remains a major global challenge for the 21st century. Worldwide, some 780 million people still lack access to improved drinking water sources. (WHO 2012)

A. *Pharmaceutical Industry*

Pharmaceutical manufacturing industries generally employ batch operations for manufacture of most basic drugs and their derivatives. Formulation units mainly employ physical operations for preparation of tablets, capsules, syrups, injections, liquid preparations, ointments etc. However, the industry is so large and the products are so diversified that it is beyond the scope of this report to describe manufacturing processes for individual drugs. The manufacturing processes are broadly classified and described in the following sections.

B. *Formulation:*

Formulation products are prepared by physical methods such as mixing, grinding, sieving, filtration, washing, drying, milling, encapsulation, packing etc. Different types of capsules, tablets, injectable, liquid tonics, syrups, ointments etc. are prepared by these methods.

C. *Extraction:*

Extraction is also a physical method and it is involved in the separation of a. useful constituent from crude or partially refined basic drugs. Suitable solvents like water, alcohol, ether, acetone or steam are used in the separation process.

Fermentation is a bio-chemical reaction within a reactor in the presence of selected active microbes or enzymes. Reactions are carried out under mild chemical and physical conditions. Various drugs like antibiotics, enzymes, hormone, vaccines etc. are manufactured by the process of fermentation.

Pharmaceutically active ingredients are generally produced by batch processes in bulk form and must be converted to dosage form for consumer use. Common dosage forms for the consumer market are tablets, capsules, liquids and ointments.

1) *Electrocoagulation*

Electrocoagulation is the process where an electrical current is introduced into an aqueous medium in an electrochemical cell, usually with an electrode. The destabilization mechanism of the contaminants, particulate suspension, and breaking of emulsions has been described in broad steps and may be summarized as follows:

1) Compression of the diffuse double-layer around the charged species, which is achieved by the interactions of ions generated by dissolution of the sacrificial electrode, due to passage of current through the solution.
2) Charge neutralization of the ionic species present in wastewater, which is caused by the counter ions, produced by the electrochemical dissolution of the sacrificial electrode. These counter ions reduce the electrostatic inter-particle repulsion sufficiently so that the van der Waals attraction predominates, thus causing coagulation. A zero net charge results in the process.
3) Floc formation, and the floc formed as a result of coagulation creates a sludge blanket that entraps and bridges colloidal particles that have not been complexed.

The chemical reactions using Iron electrode is as follows:

2) *At anode:*

$$4Fe(s) \rightarrow 4Fe^{2+}(aq) + 8e^-$$

$$4Fe^{2+}(aq) + 10H_2O(l) + O_2(g) \rightarrow 4Fe(OH)_3(s) + 8H^+(aq)$$

3) *At cathode:*

$$8H^+(aq) + 8e^- \rightarrow 4H_2(g)$$

4) *Overall Reaction:*

$$4Fe(s) + 10H_2O(l) + O_2(g) \rightarrow 4Fe(OH)_3(s) + 4H_2(g)$$

Main aim of the study is to investigate the potential of Electrocoagulation process using four Iron electrodes in bipolar mode in the removal of COD from Pharmaceutical wastewater. The effect of electrolysis time, pH and different voltages on electrode and Energy consumption is studied for the efficient treatment of Pharmaceutical wastewater.

II. MATERIAL AND METHODS

A. Analytical Measurements

The Pharmaceutical WASTWATER used in this study is collected from Hyderbad Pharmaceutical industry and brought to the labrotory and is stored in deep freezer at 4°C. The analysis of wastewater was carried out as per Standard Methods. The various characteristics of Pharmaceutical wastewater are shown in Table 1.

Sl.no	Characteristics	unit	Textile wastewater
1	pH	-	13.32
2	Color	Hazen	Black
3	Conductivity	mS/cm	46
4	Total dissolved solids	mg/L	24800
5	Suspended solids	mg/L	7950
6	Total solids	mg/L	32750
7	COD	mg/L	47466
8	Chlorides	mg/L	18398
9	Sulphate	mg/L	2130
10	Phosphate	mg/L	4580

Table 1: Characterization of Pharmaceutical wastewater

B. Experimental Set Up

The study consists of lab-scale batch system, which is composed of an electrolysis cell, a power supply system and a magnetic stirrer unit. The electrolysis cell made of BOROSIL glassbeaker with an effective volume of 1L and with bipolar electrodes in parallel connection. The Iron cathode and Iron anode consist of pieces of Iron electrodes of size 10cm × 5cm × 1mm separated by a space of 1 cm and dipped in the wastewater. The electrodes are connected to the positive and negative terminals of the DC power supply (range 30V/2A) as shown in Fig 1. In this study, an individual effect of Cell Voltage and applied pH and Electrolysis time is studied. Each experiment is of batch operation, for every regular interval of 20 minutes samples were drawn and COD concentrations are measured. At the end of each experimental (i.e. after electrocoagulation) run, the sample is transferred into another beaker and kept undisturbed for 30 minutes in order to allow the flocs that formed during electrocoagulation to settle down.

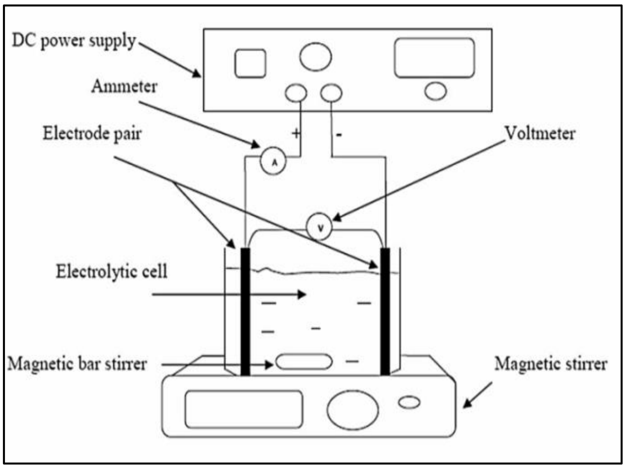

Fig. 1: Experimental Set Up

III. RESULTS AND DISCUSSION

A. Effect of Electrolysis Time

The effect of electrolysis time is investigated in the range 0 to 180 minutes with sample pH 9 as shown in Fig. 2, there is rapid increase in COD removal efficiency till 120 minutes of duration and later on approaches Equilibrium status. The maximum COD removal efficiency of 58%,65% at 8V and 10V respectively for Iron achieved in 120 minutes of electrolysis duration which is considered as optimum electrolysis duration for further studies.

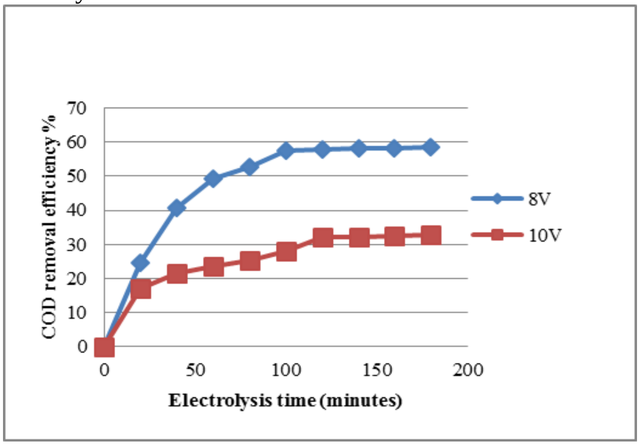

Fig. 2: Effect of Electrolysis Time

B. Effect of pH

To examine its effect, individual experiments are conducted at varying wastewater pH of 6, 7, 8, 9, 10 and 11. Fig. 3 shows the COD removals for different initial pH as a function of treatment time for Iron electrode. It was ascribed to an amphoteric behavior of $Fe(OH)_3$ which leads to soluble cations Fe^{3+} , $Fe(OH)^{2+}$ (at acidic pH) and to monomeric anions $Fe(OH)^{4-}$, $Fe(OH)_6^{3-}$ (at alkaline pH). It is well known that these species are not useful for water treatment. For these reasons the Electrocoagulation process is conducted at optimum pH 9.The maximum COD reduction using Iron plate electrodes is found to be that is 71.07% COD removal at pH 9.

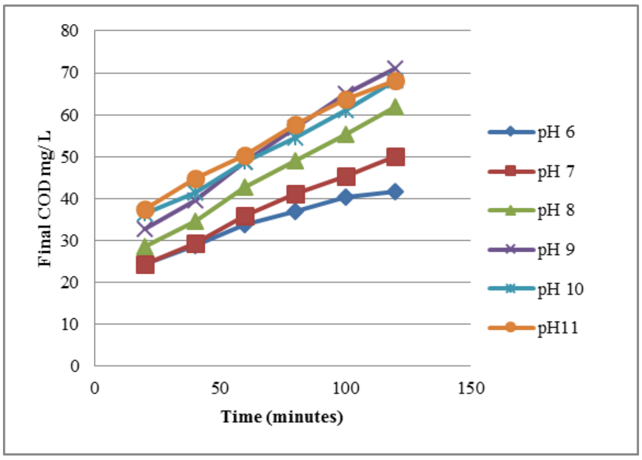

Fig. 3: Effect of Initial pH

C. Effect of Applied Voltage

To investigate the effect of applied voltage on the various parameters, EC process is carried out at 10V, 12V, 14V and 16V voltages at 1A current. Based on previous experiments 120 minutes of electrolysis time and pH 9 is maintained. This is ascribed to the fact that at higher voltage the amount of Iron oxidization increases, resulting in a greater amount of precipitate for the removal of pollutants. In addition, it is demonstrated that bubbles density increases and their size decreases with increasing current density resulting in a greater upwards flux and a faster removal of pollutants. Fig. 4 shows the maximum reduction of COD is found at 16V.

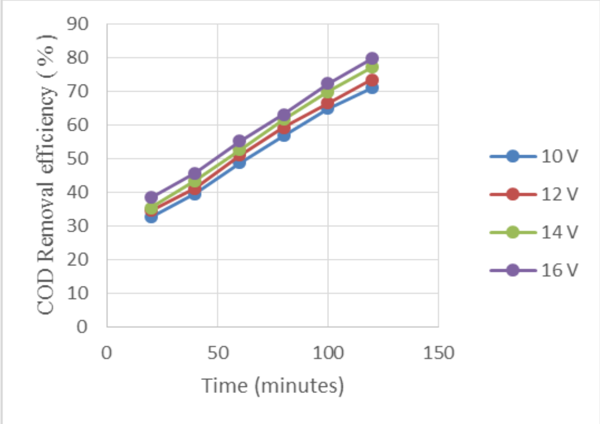

Fig. 4: Effect of Voltage on COD

D. Energy Consumption

Energy consumption is one of the important factor to be considered in treatment of pharmaceutical wastewater. It was observed that with the increase in voltage the energy consumption also increases. As shown in Fig. 5 the maximum Energy consumption of 10.81 kWH/kg of COD is observed at 16V at pH 9.

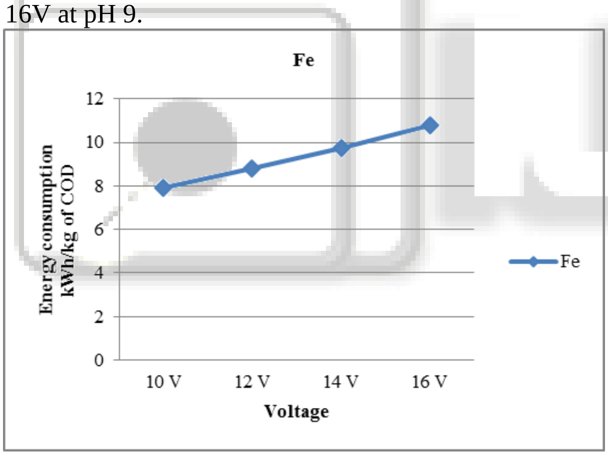

Fig. 5: Energy consumption at different voltage

IV. CONCLUSION

In this study the EC process was found to be an effective method for the treatment of Pharmaceutical wastewater. The effect of operational conditions such as electrolysis time, pH and applied voltage is examined. The result showed that

- For Iron electrode the maximum COD removal efficiency of 79.80% is found at optimum voltage of 16V at electrolysis time of 120 minutes at pH 9.
- Energy consumption of 10.81 kWH/kg of COD was observed at 16V at pH 9.

Thus, EC technology with Iron electrodes in bipolar system could be an attractive alternative for the treatment of Pharmaceutical wastewater.

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