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# Removal of Ammonical Nitrogen & COD by Electrocoagulation Process from Wastewater

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***Abstract -*** Electrocoagulation is a very unique process that has the great ability to remove wastes from water due to its high decolourization efficiency, economically attractive and relatively little sludge formation compared with other tradition processes such as biological, physical, chemical, adsorption and advanced oxidation processes. Electrocoagulation process is effective for removing a wide range of impurities like color, COD, BOD, turbidity, and metal ions removal from wastewater. This paper focuses on various studies on treatment of industrial wastewater by Electrocoagulation method depending on the mechanisms and several affected factors such as pH, current density, applied voltage, agitation speed, type, size and number of electrodes, inter electrode distance, initial concentration and electrolysis time which have been published in journals. The aim of the review is to explain the basics and up to date advancement of electrocoagulation process for the improvements in the pollutant removal efficiency. In this paper, the overview of electrocoagulation method with effect of key operational parameters on it is provided. Limitations of this method are also represented for the better understanding of the mechanism of pollutant removal and its optimization.

***Keywords -*** Aluminium electrodes , COD, Electrocoagulation process, Wastewater treatment, Effluent treatment

## 1. Introduction

Electrocoagulation (EC) is the electrochemical technique for treating polluted water using electricity instead of the expensive chemical reagents. It has been successly applied for the treatment of soluble or colloidal pollutants in various industrial effluents including, effluent issues from food industries, tanneries, mechanical workshop (soluble oil) polymerization manufacture, and effluent of textile industries that containing heavy metals, suspensions solids, emulsified organics and many other contaminants. Electrocoagulation gives the better advantages to removing the smallest and colloidal particles compared with the other traditional flocculation–coagulation processes, such charged particles have the greater probability of being coagulated and destabilized because of the electric field that sets them in motion. In an addition, electrocoagulation and flotation are capable of the reducing waste production from the wastewater treatment process and also reduces the time necessary for treatment. Electrocoagulation has a long history as a water treatment technology having been employed to remove the wide range of pollutants. EC was the first proposed in London by Vik et al., in 1889 where the sewage treatment plants are built and electrochemical treatment has been used via mixing the domestic wastewater with saline (sea) water. The principle of electrocoagulation was first patented in 1906 by the A. E. Dietrich and were used to treat bilge wastewater from ships. In the United States J.T. Harries awarded a patent In 1909 for wastewater treatment by electrolysis using sacrificial aluminum and iron anodes. Therefor after, a wide range of water and effluent applications followed under a variety of conditions. Coincide with the recent times of the concerns about the pollution, industries become under great pressure to find innovative ways & techniques to comply with environmental regulations, electrocoagulation has been re-emerged as a viable technology. In this paper, electrocoagulation of industrial wastewater process applications were described. The literature published from 2009 to 2013 related to the electrocoagulation process within the wastewater has been presented with special emphasis placed in the several sections of treatment. Such as optimization & the modeling, various wastewater treatment techniques, analytical, instrumentations, and comparison with the other and better treatment methods as well as sacrificial electrode materials and electrical energy requirements for treatment.

## 2. Principle of Electrocoagulation

Electrocoagulation is the process of destabilization of the contaminants like (suspended, emulsified, or dissolved) happens by oxidation and reduction because of application of electric current to the electrolytic solution. Electrocoagulation is an alternative electrochemical treatment method that has gained increasing attention in recent years due to its simple operation, high removal efficiency, little sludge production and requiring less chemicals. It is considered as the effective & better method for treating many different types of wastewater with high color removal efficiency and relatively less sludge formation[3]. This technique is an indirect electrochemical method which produces the coagulant agents ions such as ($Fe^{+3}$or $Al^{+3}$) from the electrode materials(Fe or Al) in aqueous medium. These species, that is $Fe(OH)_3$ can remove dissolved contaminants by precipitation or by the floatation. In an EC process the coagulating ions are the produced "in situ"[11].

## 3. Mechanism of Electrocoagulation

It consist of the following stages:

1- Formation of the coagulants by the electrolytic oxidation of sacrificial electrode.

2- Destabilization of contaminants, particulate suspension and the breaking of emulsions.

3- Aggregation of destabilized particles to form the flocs.

4- Removal of colloids by sedimentation or floatation process.

Destabilization mechanism in EC process plays an major role; it contains the following steps.

1. Cationic hydrolysis process neutralizes negatively charged colloids.

2. Flocs formation, the floc formed as a result of coagulation creates a sludge blanket that entraps and contaminants are removed in the form of hydroxide precipitates.[9]

### 3.1 Process Reactions

The main plate of electrodes that are commonly used for electrocoagulation are iron and aluminum. The main reaction take place at the metal electrodes.[8]

Iron Electrode (Anodic reactions)

Anode: $Fe \rightarrow Fe^{2+} + 2e^{-}$ --- (1)
Cathode: $2H_2O + 2e^{-} \rightarrow H_2 + 2OH^{-}$ --- (2)
Overall: $Fe^{2+} + 2H_2O \rightarrow H_2 + Fe(OH)_2$ --- (3)

OR

Anode: $Fe \rightarrow Fe^{3+} + 3e^{-}$ --- (4)
Cathode: $3H_2O + 3e^{-} \rightarrow 3/2H_2 + 3OH^{-}$ --- (5)
Overall: $Fe^{3+} + 3H_2O \rightarrow 3/2H_2 + Fe(OH)_3$ --- (6)

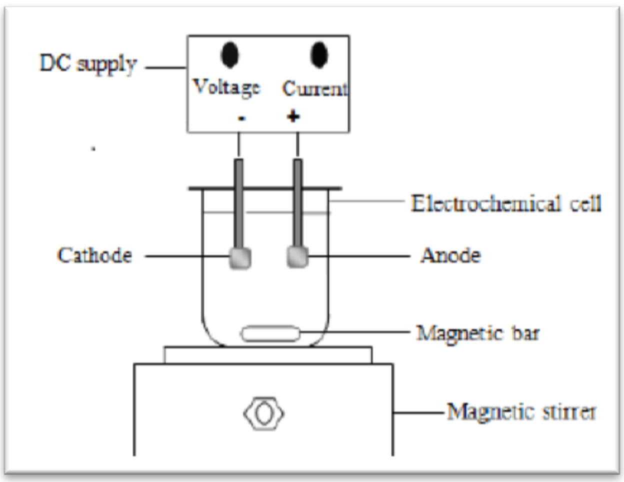
OR

Aluminum Electrodes

Anode: $Al \rightarrow Al^{3+} + 3e^{-}$ --- (7)

Cathode: $3H_2O + 3e^- \rightarrow 3/2H_2 + 3OH^-$ ---- (8)
Overall: $Al^{3+} + 3H_2O \rightarrow 3/2H_2 + Al(OH)_3$ ---- (9)

**In general:**
Anode: $M \rightarrow Mn^+ + ne$ ---- (10)
Cathode : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ---- (11)
Overall : $Mn^+ + nH_2O \rightarrow nH^+ + M(OH)_n$ ---- (12)




**3.2 Parameters affecting Electrocoagulation process**

There are numbers of parameters which affects electrocoagulation. These parameters includes the following: materials of electrodes, electrodes arrangements, pH effects. current density, time of treatment, temperature effects, inter electrode distance, and the types of power supply.

**3.2.1 Electrode material**

Material selection depends on the different type of contaminants and also depends on the chemical characteristics of the electrolytes. Generally, aluminum is better than iron in most cases it gives effective results than others. Aluminum electrodes were most effective in removing the dye of the effluent, where as iron electrodes removes phenol and the wastewater more effectively than aluminum electrodes. A combination of aluminum and iron electrodes removed dye, COD, and phenol with high efficiency.[6]

Combination electrodes have been studied for the contaminants such as arsenic removal from groundwater. Iron electrodes and a combination of iron and aluminum electrodes gave the highest removal efficiencies for removal of arsenic. Similarlly results were obtained for copper, chromium and nickel removal from electroplating wastewater. Fe-Al pair has been most effective in removing the indium, arsenic from water.[1]

### 3.2.2 Inter-electrode Distance

Inter-electrode distance plays an major role on electrocoagulation process because the electrostatic field depends on the distance between the anode and the cathode. Minimum inter-electrode distance provides low pollutant removal efficiency. An minimal distance between the electrodes provides maximum pollutant removal efficiency. The more the inter electrode distance the decreases the movement of productuced ions.[4]

The larger the inter electrode distance, the greater should be the difference in applied power supply, so the solution presents higher resistivity to the electrical current. According to the characteristics of the wastewater, the process efficiency can be improved by varying the distance between the electrodes and power supply will also vary accordingly.[5]

### 3.2.3 Effect of the temperature

The effect of temperature on the removal of the pollutants through EC has been studied in a several research papers. The effect of solution temperature on boron removal by EC is studied in the range of the 293–333K[1]. When temperature increased from the 293 K to 333 K, the boron removal efficiency increased from 84% to 96%. The reverse is the case when paper mill wastewater was treated at temperatures between 293 and 333 K. Removal of color, COD, and phenol decreased by 10–20% when temperature increased from the 293 K to 333 K[1]

Results indicate that increasing temperature has a negative effect on the removal. However, it should be noted that the operation of electrocoagulation process at higher temperature significantly reduced electrical energy consumption. So, the production of hydroxide species increases rapidly then it enhances value of pH. The increase in pH may be affecting on to the iron and aluminum electrode to be in the oxide form and didn't exist in the hydroxide form which is the coagulant that should remove the color.[2]

### 3.2.4 Effect of pH

The pH of the solutions is as a major parameter before treatment because it affects the conductivity of the solution, dissolution of the electrodes, speciation of hydroxides, and ζ-potential of colloidal species. pH helps in precipitation of pollutants if the solution achieve desirable pH and it have the better efficiency of contaminants removal. Both low and high pH values from the optimum value to decrease the removal efficiency.[3]

In the wastewater treatment process initial pH plays an important role, either in chemical coagulation or EC. However, EC is more appropriate in a wide range of pH, while chemical coagulation is added if pH is high.

pH increases the dissolved iron weight during the electrocoagulation process increases due to the formation of iron hydroxide species which absorb the color molecules and causes to the increase of the removal efficiency. The effect of pH on the process performance is explained as below: the iron species are different according to the solution pH; at alkaline pH, dye removal efficiency is increased as the concentration of $OH^-$ ion increases which help in formation of the different iron hydroxide complexes.[4]

### 3.2.5 Current density and time of treatment

Current density is a major factor because it analyzes the coagulant dosage rate, bubble formation rate, size, and development of flocs, as they affect the efficiency of the electrocoagulation process. The anode dissolution rate is the directly proportional to the current density. However, it is an increase in current density beyond the optimum value has no effect on the contaminant removal efficiency.[5]

At the high current density, there is wastage of electrical energy in heating up of water which results in decrease in current efficiency. The current density must be selected as in according to the other operating parameters such as pH, temperature and flow rate. In the electrocoagulation process, current density and the types of the anions define the current efficiency.[5]

### 3.2.6 Advantages and Disadvantages

EC process is easy to operate. It needs a simple type of equipment. It is the low sludge producing process. EC generated Sludge is mainly composed of the metallic oxides/hydroxides.There are no additional chemicals required for EC process. It requires less maintenance than other processes. The process requires less type of civil works and other constructions. Flocs formed by EC process tends to be the much larger. EC process is used to removes the smallest colloidal particles and it gives a clear, colorless and odourless water.

The sacrificial anodes need to be replaced periodically and the use of electricity may be expensive in some of the cases. High conductivity of the effluent suspension is required. The high cost of the electricity can result in an increase in operational.

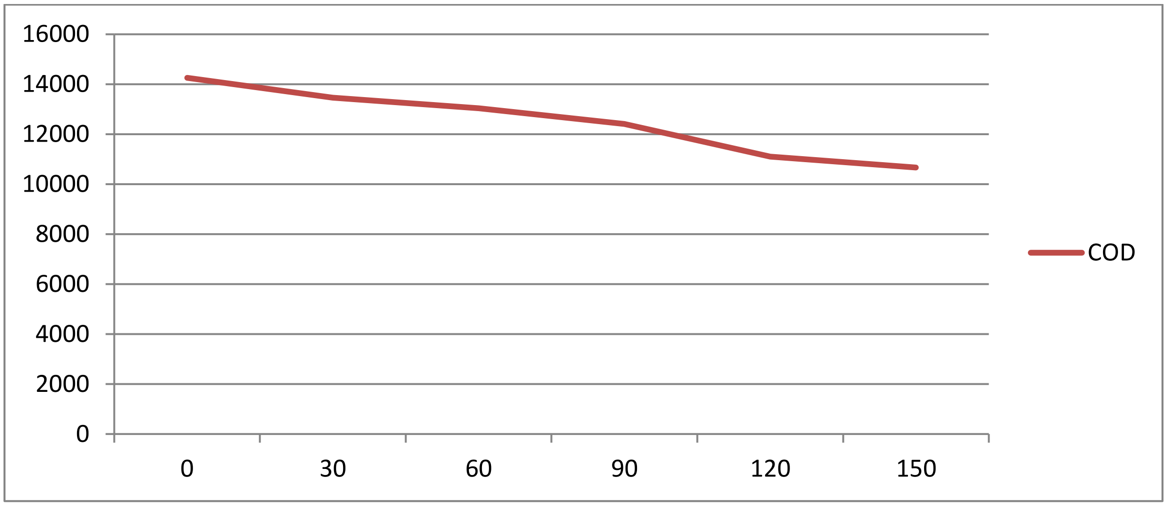
## 4. Result & Discussion

- **Results of Pharmaceutical Industrial wastewater ( at pH 2)**

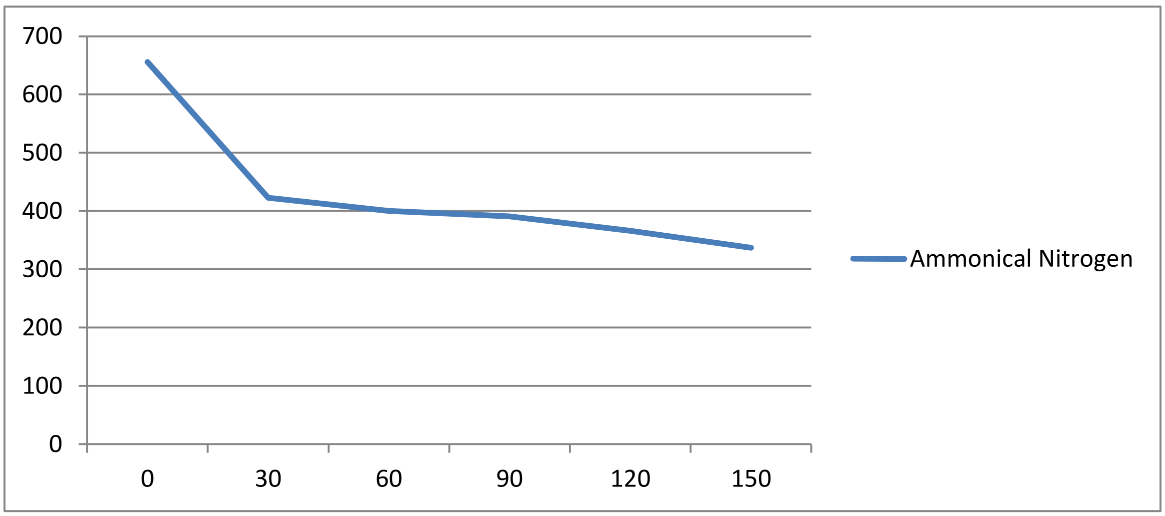
| Sr. no. | Time interval (mins) | Ammonical nitrogen(mg/l) | COD(mg/l) |
|---|---|---|---|
| 1. | 0 | 656 | 14256 |
| 2. | 30 | 423 | 13456 |
| 3. | 60 | 400 | 13068 |
| 4. | 90 | 391 | 12400 |
| 5. | 120 | 366 | 11100 |
| 6. | 150 | 337 | 10663 |
| 7. | 180 | 290 | 9870 |

**Table:2 Readings of Pharmaceutical Industrial wastewater**

From table 2 experimental results showed that using Aluminum electrodes, NH4-N removal reached nearly by 290 mg/L from initial value 656 mg/l after treating waste for 180 minutes at pH 2. About 55.7 % removal of Ammonical nitrogen can be removed by electrocoagulation Process. COD removal at that time was observed to be reduced by 30.7 % which is having the initial value 14256 mg/l and final value 9870 mg/l. Below figure shows the graphical representation of reduction of NH4-N by using Al Electrode at the condition of Current: 1.48-1.50 A and Voltage 4V.




**Graph:1 COD reduction in in pharmaceutical wastewater**



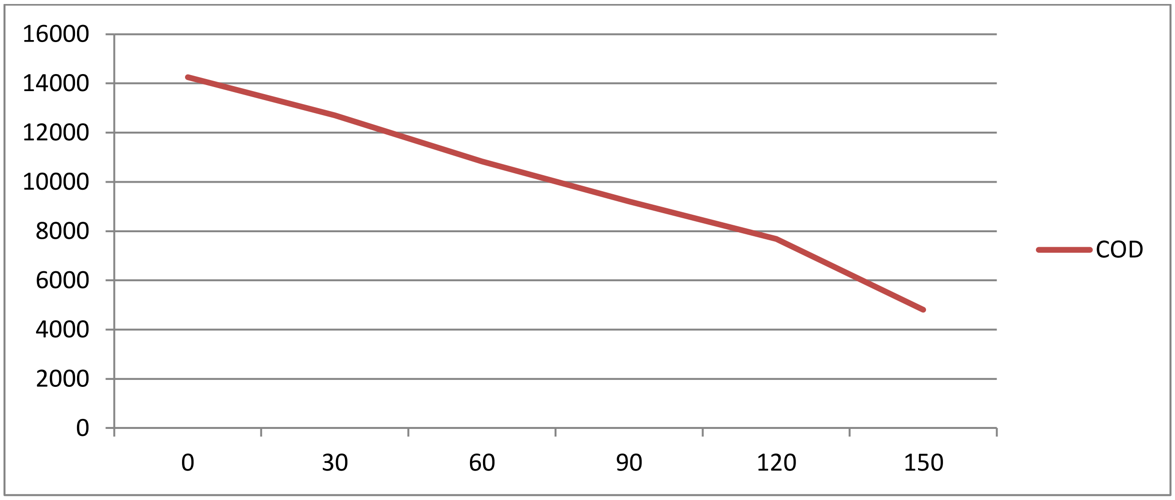

**Graph:2 Ammonical Nitrogen reduction in pharmaceutical wastewater**

- **Results of Pharmaceutical industrial wastewater ( at pH 9)**

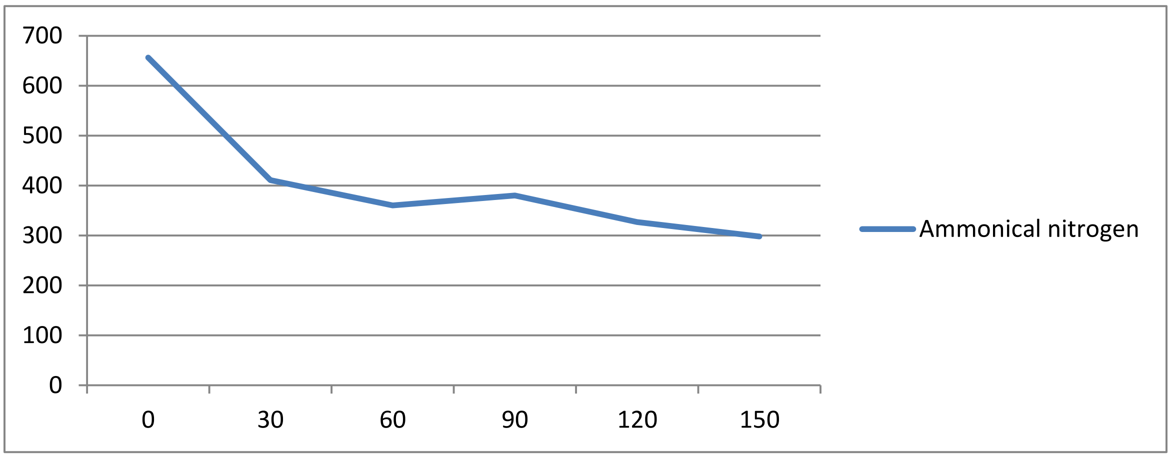
| Sr. No | Time interval (mins) | Ammonical nitrogen(mg/l) | COD(mg/l) |
|---|---|---|---|
| 1. | 0 | 656 | 14256 |
| 2. | 30 | 411 | 12700 |
| 3. | 60 | 380 | 10825 |
| 4. | 90 | 360 | 9200 |
| 5. | 120 | 327 | 7680 |
| 6. | 150 | 298 | 4805 |
| 7. | 180 | 270 | 2570 |

**Table:3 Readings of Pharmaceutical Industrial wastewater**

From table 3 experimental results showed that using Aluminium electrodes, NH4-N removal reached nearly by 270 mg/L from initial value 656 mg/l after treating waste for 180 minutes at 9 pH. About 57.9 % removal of Ammonical nitrogen can be removed by electrocoagulation Process. COD removal at that time was observed to be reduced by 81.9% which is having initial value 14256 mg/l and final value 2570 mg/l.




**Graph:3 COD reduction in in pharmaceutical wastewater**



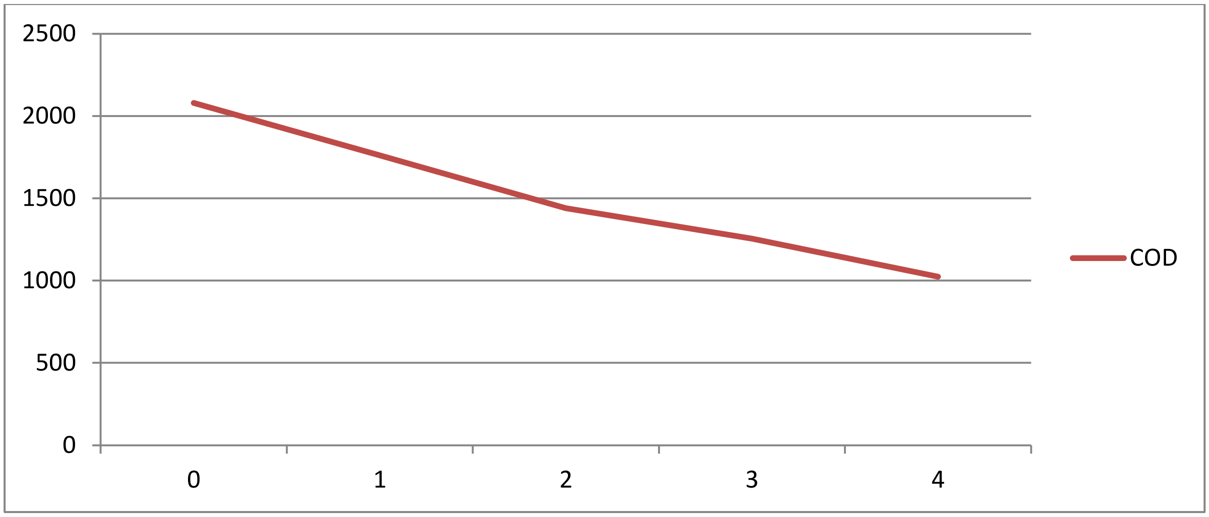

**Graph:4 Ammonical Nitrogen reduction in pharmaceutical wastewater**

- **Results of Dyes Industrial wastewater( at pH 3)**

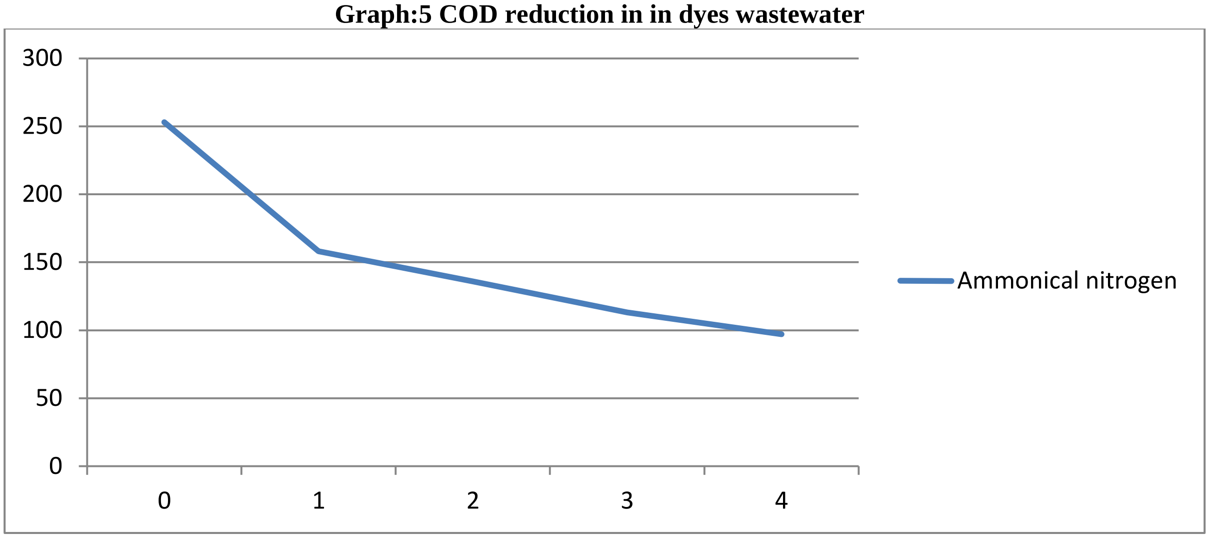
| Sr. No | Time interval(hrs) | Ammonical nitrogen(mg/l) | COD(mg/l) |
|---|---|---|---|
| 1. | 0 | 253 | 2080 |
| 2. | 1 | 158 | 1760 |
| 3. | 2 | 136 | 1440 |
| 4. | 3 | 113 | 1256 |
| 5. | 4 | 97 | 1023 |

**Table:4 Readings of Dyes Industrial wastewater**

From table 4 experimental results showed that using Aluminium electrodes, NH4-N removal reached nearly by 97 mg/L from initial value 253 mg/l after treating waste for 4 hours at 3 pH. About 61.6 % removal of Ammonical nitrogen can be removed by electrocoagulation Process. COD removal at that time was observed to be reduced by 50.8% which is having initial value 2080 mg/l and final value 1023 mg/l.




**Graph:5 COD reduction in in dyes wastewater**



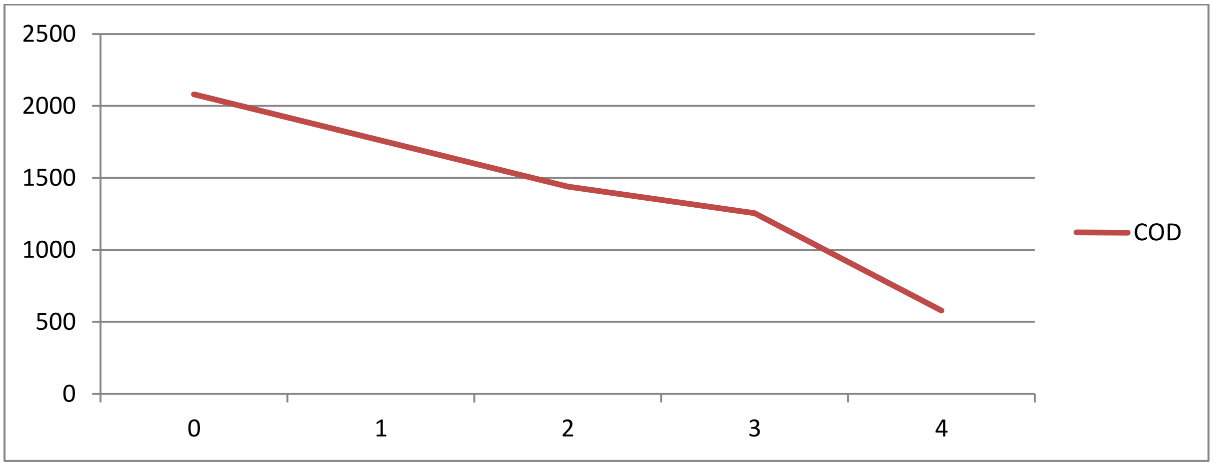

**Graph:6 Ammonical Nitrogen reduction in dyes wastewater**

- **Results of Dyes Industrial wastewater( at pH 8)**

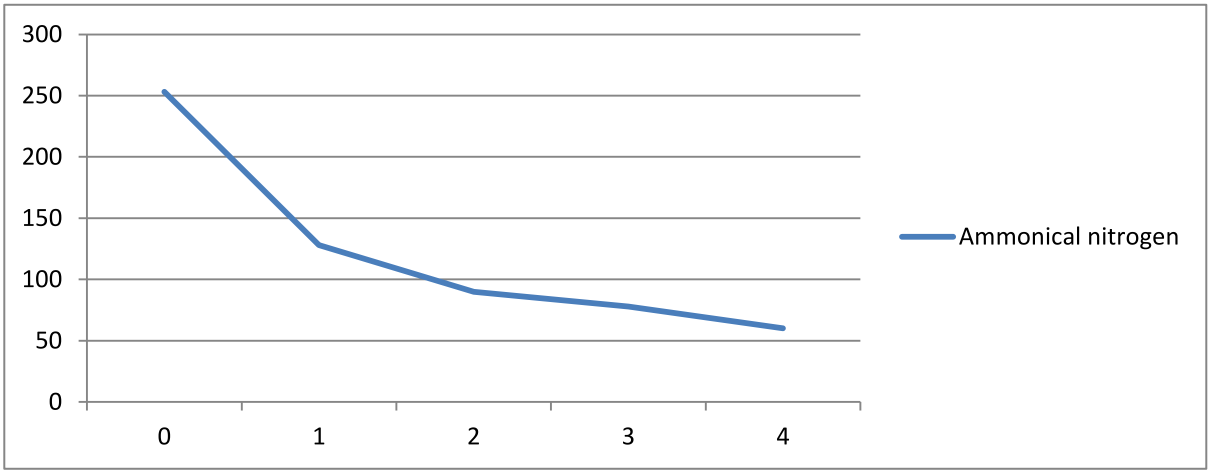
| Sr. No | Time interval(hrs) | Ammonical nitrogen(mg/l) | COD(mg/l) |
|---|---|---|---|
| 1. | 0 | 253 | 2080 |
| 2. | 1 | 128 | 1760 |
| 3. | 2 | 90 | 1440 |
| 4. | 3 | 78 | 1256 |
| 5. | 4 | 60 | 580 |

**Table: 5 Readings of Dyes Industrial wastewater**

From table 5 experimental results showed that using Aluminium electrodes, NH4-N removal reached nearly by 60 mg/L from initial value 253 mg/l after treating waste for 4 hours at 8 pH. About 76.2% removal of Ammonical nitrogen can be removed by electrocoagulation Process. COD removal at that time was observed to be reduced by 72.1% which is having initial value 2080 mg/l and final value 580 mg/l.




**Graph:7 COD reduction in in dyes wastewater**




**Graph:8 Ammonical Nitrogen reduction in dyes wastewater**

## 5. Conclusion

The experiment is based on the electrocoagulation of the different industrial wastewater with high concentration of COD and Ammonical nitrogen for determining the effects of operating parameters such as pH, voltage and electrolysis time on COD and Ammoniacal nitrogen removal. Initially the experiment was carried out at pH 2 for pharmaceutical industry the efficiency of COD and Ammonical nitrogen were 30.7% and 55.7% respectively. After increasing pH up to 9 the efficiency of COD and Ammonical nitrogen were 81.9% and 58.8% respectively. For dye industrial wastewater the efficiency of COD and Ammonical nitrogen at pH 3 were 50.8% and 61.6% respectively. after at pH 8 the efficiency of COD and Ammonical nitrogen were 72.1% and 76.2% respectively.

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