A Study on waste water Treatment of Chemical Industry using Electro-coagulation

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ABSTRACT

The electro-coagulation is one of the best techniques used for the treatment of industrial wastewaters. Electro-coagulation is derived from the conventional coagulation technique. The cations are generated in solution by electrolytic dissolution of the metal electrodes. This paper reports a research work on wastewater treatment by eletrocoagulation of an chemical industry manufacturing of 'Thalic Acid'. The goal is to treat the wastewater coming from chemical industries using a Electro-coagulation Technology by using different electrodes. i.e. Mild Steel, Aluminum, Graphite electrodes, different current density is applied in the experiment & experiment was performed at time interval of 5min, 10min, 15min . The experiments show that the reduction in COD is increase by increasing process time & current density. It also concluded that the Iron electrode gives better COD reduction

Keyword : - *Electro-coagulation, Electrodes , Chemical oxygen demand*

1. INTRODUCTION

The wastewater generated from chemical industries contains very harmful pollutants to the environment. To reduce their negative effects, several treatment processes including physicochemical techniques, are implemented viz., adsorption, ion exchange, precipitation, reverse osmosis , coagulation.

Electro-coagulation (EC) technique is derived from the coagulation-flocculation. It has been successfully used in the treatment of various emissions : water washing, discharges of oil, water containing metal ions such as arsenic, copper, lead, cadmium, iron, chromium. Electrocoagulation has become a rapidly growing area of wastewater treatment due to its ability to remove contaminants that are generally more difficult to remove by filtration or chemical treatment systems, such as emulsified oil, total petroleum hydrocarbons, refractory organics, suspended solids, and heavy metals. There are many brands of electrocoagulation devices available and they can range in complexity from a simple anode and cathode to much more complex devices with control over electrode potentials, anode consumption, cell REDOX potentials as well as the introduction of ultrasonic sound, ultraviolet light and a range of gases and reactants to achieve so-called Advanced Oxidation Processes for refractory or *recalcitrant* organic substances.

2. NEED OF THE STUDY

A number of studies found trace concentrations of chemicals in wastewater, various water sources and some drinking-waters in India. Effluent sample was collected from thalic acid manufacturing unit, where the conventional treatment units are not efficient to get the desired results.

Hence it is required to treat the effluent through other innovative treatment technology i.e. Electro-coagulation. The reason is the intention to create clean technologies that can substitute the currently used "environmentally unfriendly" conventional facilities.

3. Electrocoagulation Process:-

The electrocoagulation process is based on valid scientific principles involving responses of water contaminants to strong electric fields and electrically induced oxidation and reduction reactions. This process is able to take out over 99 percent of some heavy metal cations and also appears to be able to electrocute microorganisms in the water. It is also able to precipitated charged colloids and remove significant amounts of other ions, colloids, and emulsions. When the system is in place, the operating costs including electric power, replacement of electrodes, pump maintenance and labor cost can be less than 4 INR per thousand liters for some applications.

Coagulation is one of the most important physiochemical operation used in wastewater treatments. This is a process used to cause the destabilization and aggregation of smaller particles into larger particles. Water contaminants such as ions (heavy metals) and colloids (organics and inorganics) are primarily held in solution by electrical charges. The colloidal systems could be destabilized by the addition of ions having a charge opposite to that of the colloid. The destabilized colloids can be aggregated and subsequently removed by sedimentation and/or filteration. Coagulation can achieve by electric current, which called electrocoagulation process. Electrocoagulation can often neutralize ion and particle charges, thereby allowing contaminants to precipitated, reducing the concentration below that possible with chemical precipitation, and can replace and/or reduce the use of expensive chemical agents (metal salts, polymer).

Reactions at the electrodes

Electrocoagulation can be made when a potential is applied from external power source to electrodes. In case of a simple electrocoagulating reactor formed by one anode and one cathode (Figure 1), some reactions and electrochemical reactions occur. They are summarized as follows (Case of EC with aluminium electrodes:

- Reduction of water in the cathode: $6H_2O + 6e^- \rightarrow 3H_2 + 6OH^-$
- Formation of Al(III) in the anode: $2Al \rightarrow 2Al^{3+} + 6e^-$

When the pH is favorable, these two species can react to form Al(OH)3 according to the following reaction:

$$Al^{3+} + 3OH^- \leftrightarrow Al(OH)_3$$

- Attack of the cathode for alkaline pH:

$$2Al(s) + 6H_2O + 2OH^-(aq) \rightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$$

- Formation of oxygen in the anode and hydrogen in the cathode by electrolyze of water.

$$2H_2O(l) \rightarrow 4H^+(aq) + O_2 + 4e^-$$

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

The gases released by the EC contribute to the elimination of a part of the suspended matters by electro flotation (EF). The small size of gas bubbles allows them to join efficiently to the suspended solid material.
Cations released through the EC eliminate a lot of pollutants (Suspended and colloidal matters, dyes, heavy metals) by electrostatic destabilization or by adsorption on the metal hydroxide flocs or its polymers. The main advantages of electrocoagulation process highlighted by several authors [19-20] are the highly chemically reactive M^{n+}, OH^- and superoxide HO_2^- radicals, the compactness of the installations, the lower volume of sludge, the removal of colloidal particles of small size, the induced flotation brings the pollutants to the surface, the cathodic reduction of impurities, the electrophoretic migration of the ions in solution, the reduction of metal ions at the cathode, other electrochemical and chemical processes.
Nevertheless, this technique has some disadvantages:

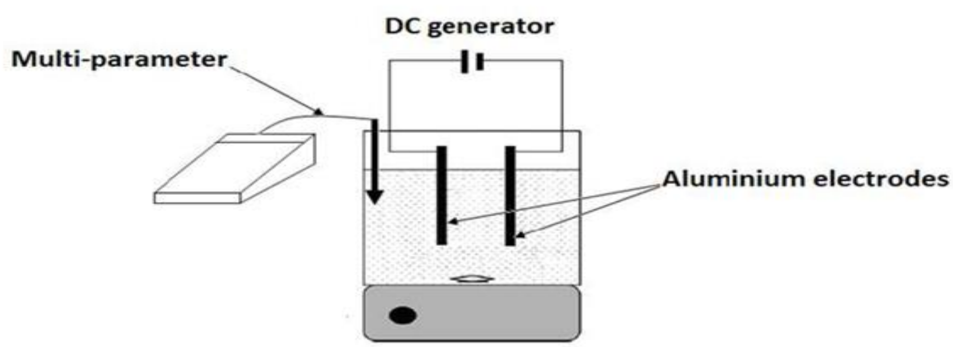
- High coast, if large consumption of electrodes.
- Electrodes must be replaced regularly.
- Need for having electrical energy.
- Formation of an oxide film on the cathode, making thus difficult the electronic transfer and thereafter the effectiveness of EC.
- Need to have a good conductivity in some discharges cases.

4. WORKING OF ELECTROCOAGULATION

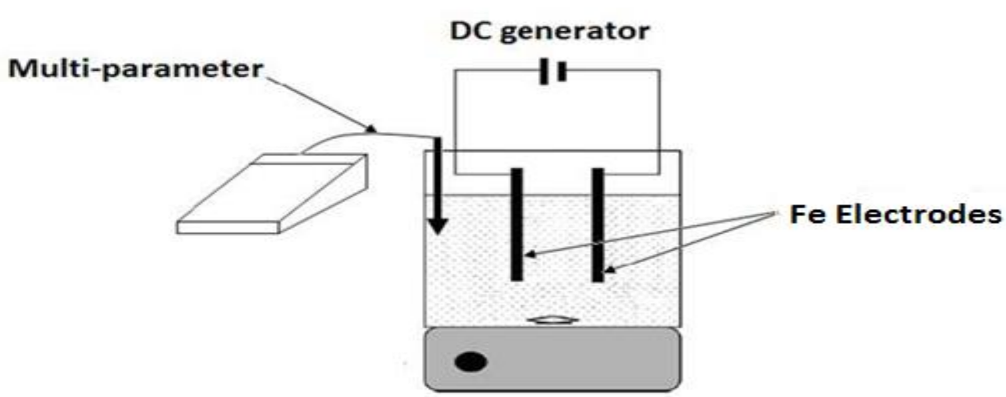
Electrocoagulation involves several chemical and physicochemical phenomena due to electrolysis. Generally three steps occur in a successive way: (i) formation of coagulants by dissolution of anode (sacrificial electrode), (ii) coagulation of contaminants and particulate suspension and breaking of emulsions and (iii) aggregation of the destabilized by flocuation or adsorption on the metal hydroxide flocs or its polymers.

5. MATERIALS AND METHODOLOGY

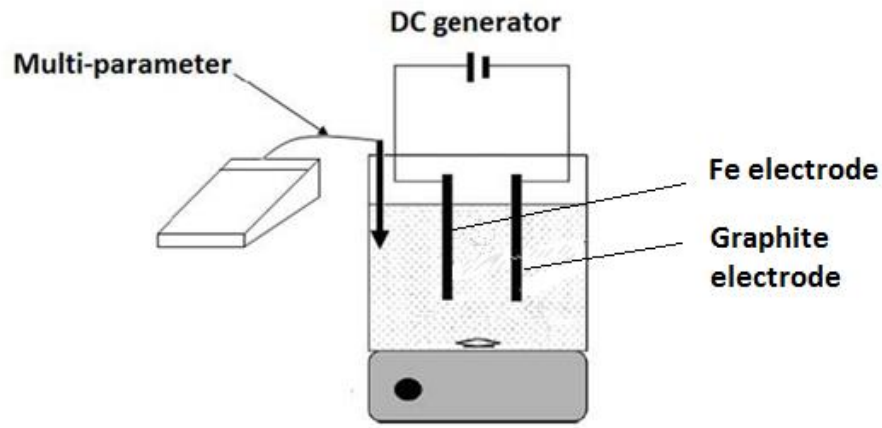
The EC experiments were performed on the settled wastewater of chemical industry, Thalic acid manufacturing industry with two aluminum electrodes. The electrodes have the following dimensions: length = 8 cm, width = 5 cm, thickness = 0.5 cm and an active surface of 30 cm^2. The distance between electrodes was 1 cm. This was necessary to ensure a good mix between Al^{3+} and OH^-. During testing, samples of 200 ml were taken by means of a hose connected to the reactor at intervals of 5 min, 10min, 15min. the experiment was done for the current density of 5 mA/cm^2,10 mA/cm^2,15 mA/cm^2. The measured parameters were pH, COD.



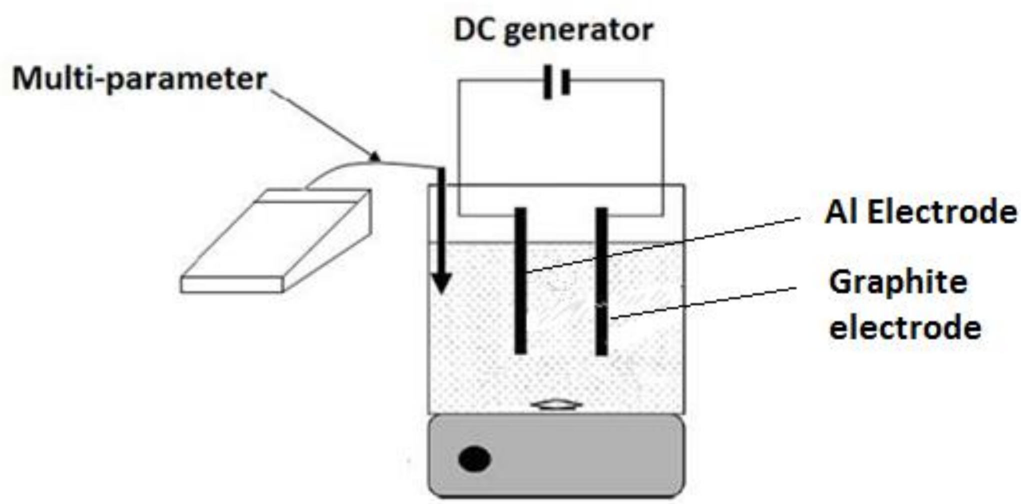
The other experiments were performed on the settled wastewater of chemical industry, Thalic acid manufacturing industry with two mild steel electrodes. The electrodes have the following dimensions: length = 8 cm, width = 5 cm, thickness = 0.5 cm and an active surface of 30 cm^2. The distance between electrodes was 1 cm. This was necessary to ensure a good mix between Fe^{2+} and OH^-. During testing, samples of 200 ml were taken by means of a hose connected to the reactor at intervals of 5 min, 10min, 15min. the experiment was done for the current density of 5 mA/cm^2,10 mA/cm^2,15 mA/cm^2. The measured parameters were pH, COD.



Then the experiment was done by placing graphite electrode as a cathode & placing Al & Fe electrode as a anode. The electrodes have the following dimensions: length = 8 cm, width = 5 cm, thickness = 0.5 cm and an active surface of 30 cm^2. The distance between electrodes was 1 cm. During testing, samples of 200 ml were taken by means of a hose connected to the reactor at intervals of 5 min, 10min, 15min. the experiment was done for the current density of 5 mA/cm^2,10 mA/cm^2,15 mA/cm^2. The measured parameters were pH, COD.



Experiment -1
As Fe as a anode & Graphite as cathode



Experiment -2
Fe as a anode & Graphite as cathode

6. RESULTS

The characteristics of wastewater taken from 'Thalic acid' manufacturing units are described in the table. The various tests were conducted on the wastewater as per procedure laid down in standard methods.

Table 1: Characteristics of dairy waste water

No.	Parameter	Concentration, mg/L
1	pH	4.1
2	Total Dissolved Solids (mg/L)	59305
3	Oil & Grease (mg/L)	2.4
4	COD (mg/L)	7360
5	BOD (mg/L)	900
6	Ammonical nitrogen (mg/L)	40.6

6.1 PERFORMANCE OF ELECTROCOAGULATION BY USING IRON ELECTRODE AS ANODE & CATHODE AT DIFFERENT DETENTION TIME

Table 2: Performance of electrocoagulation on removal of COD at different detention time

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	5 mins	15 mA/cm^2	7360	5805	21.12%
	10 mins	15 mA/cm^2	7360	4369	40.63%
	15 mins	15 mA/cm^2	7360	3150	57.20%
	20 mins	15 mA/cm^2	7360	1574	78.61%

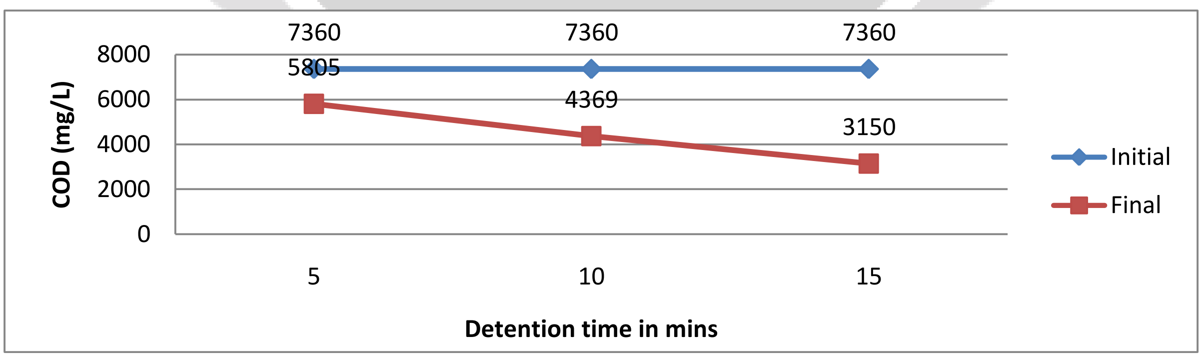


Chart 1: Performance of electrocoagulation on removal of COD at different detention time

6.2 PERFORMANCE OF ELECTROCOAGULATION BY USING ALUMINUM ELECTRODE AS ANODE & CATHODE AT DIFFERENT DETENTION TIME

Table 3: Performance of of electrocoagulation on removal of COD at different detention time

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	5 mins	15 mA/cm^2	7360	5822	20.89%
	10 mins	15 mA/cm^2	7360	4540	35.31%
	15 mins	15 mA/cm^2	7360	3356	54.39%
	20 mins	15 mA/cm^2	7360	2120	71.19%

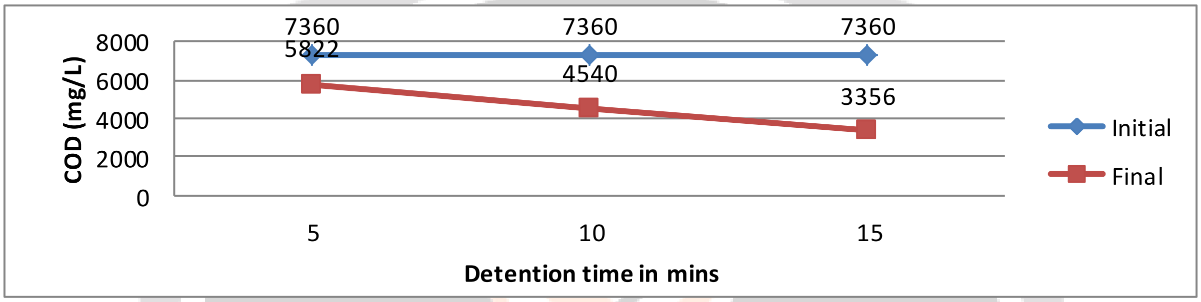


Chart 2: Performance of electrocoagulation on removal of COD at different detention time

6.3 PERFORMANCE OF ELECTROCOAGULATION BY USING IRON ELECTRODE AS ANODE & CATHODE FOR DIFFERENT CURRENT DENSITY

Table 4: Performance of electrocoagulation on removal of COD for different current density

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	10 mins	15 mA/cm^2	7360	4369	40.63%
	10 mins	10 mA/cm^2	7360	4672	36.52%
	10 mins	5 mA/cm^2	7360	5064	31.19%

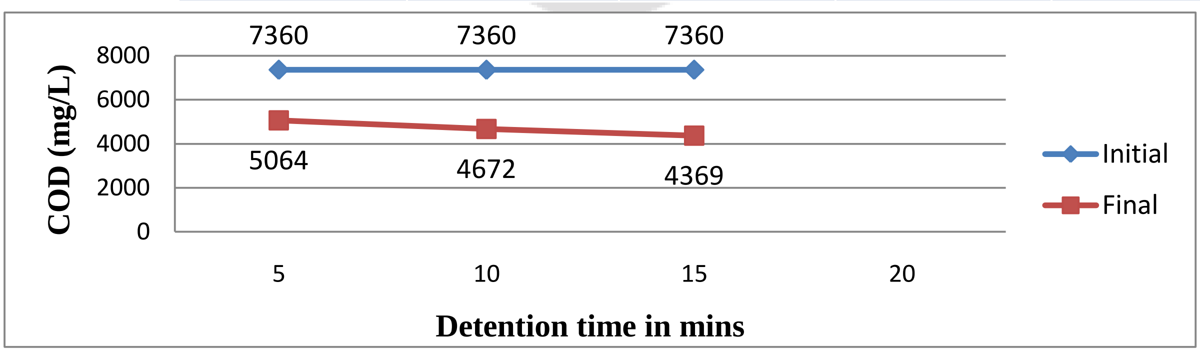


Chart 3: Performance of electrocoagulation on removal of COD for different current density

6.4 PERFORMANCE OF ELECTROCOAGULATION BY USING ALUMINUM ELECTRODE AS ANODE & CATHODE FOR DIFFERENT CURRENT DENSITY

Table 5: Performance of electrocoagulation on removal of COD for different current density

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	10 mins	15 mA/cm^2	7360	4540	38.31%
	10 mins	10 mA/cm^2	7360	4916	33.20%
	10 mins	5 mA/cm^2	7360	5277	28.29%

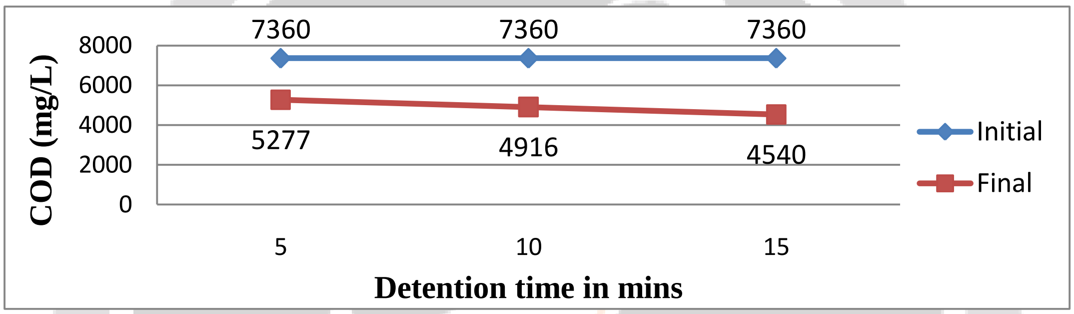


Chart 4: Performance of electrocoagulation on removal of COD for different current density

6.5 PERFORMANCE OF ELECTROCOAGULATION ON REMOVAL OF COD USING Fe ELECTRODE AS A ANODE & GRAPHITE ELECTRO AS A CATHODE AT DIFFERENT DETENTION TIME

Table 6: Performance of of electrocoagulation on removal of COD at different detention time

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	5 mins	15 mA/cm^2	7360	6320	14.13%
	10 mins	15 mA/cm^2	7360	5697	22.99%
	15 mins	15 mA/cm^2	7360	4634	37.03%
	20 mins	15 mA/cm^2	7360	3803	48.32%

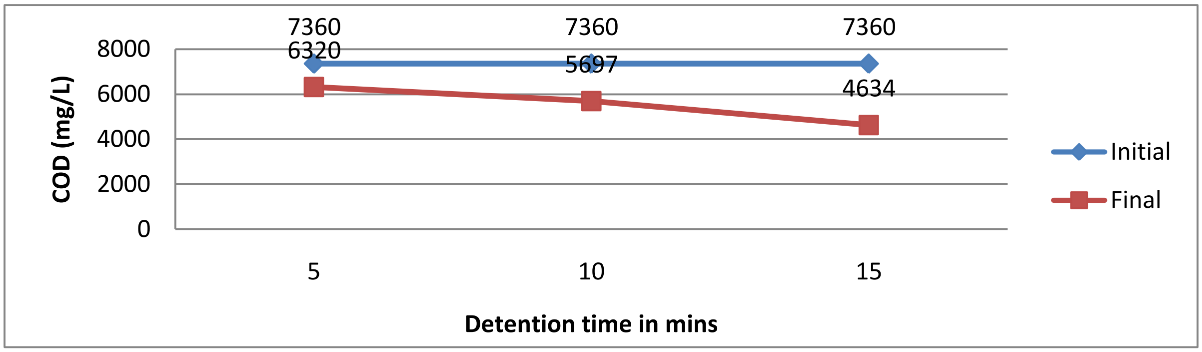


Chart 5: Performance of electrocoagulation on removal of COD at different detention time

6.6 PERFORMANCE OF ELECTROCOAGULATION ON REMOVAL OF COD USING ALUMINUM ELECTRODE AS A ANODE & GRAPHITE ELECTRO AS A CATHODE AT DIFFERENT DETENTION TIME

Table 7: Performance of of electrocoagulation on removal of COD at different detention time

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	5 mins	15 mA/cm^2	7360	6489	11.83%
	10 mins	15 mA/cm^2	7360	5952	19.13%
	15 mins	15 mA/cm^2	7360	5094	30.78%
	20 mins	15 mA/cm^2	7360	4221	42.64%

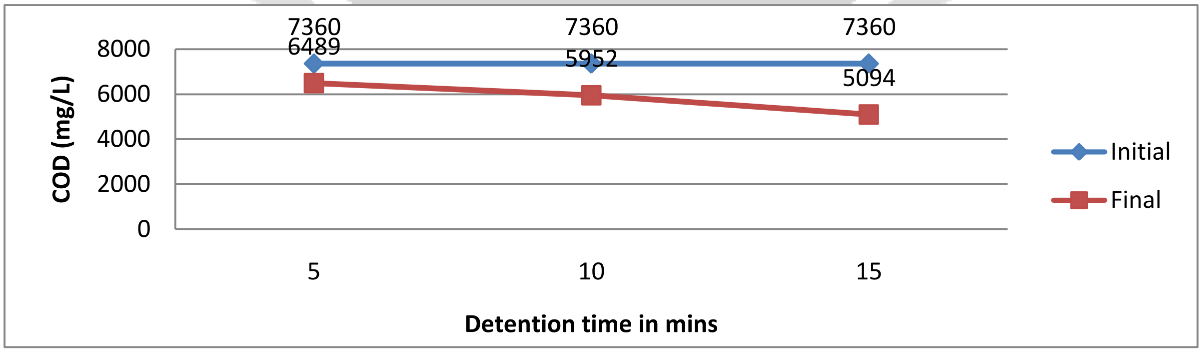


Chart 6: Performance of electrocoagulation on removal of COD at different detention time

6.7 PERFORMANCE OF ELECTROCOAGULATION BY USING IRON ELECTRODE AS ANODE & GRAPHITE ELECTRODE AS CATHODE FOR DIFFERENT CURRENT DENSITY

Table 8: Performance of electrocoagulation on removal of COD for different current density

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	10 mins	15 mA/cm^2	7360	4985	32.26%
	10 mins	10 mA/cm^2	7360	5697	22.59%
	10 mins	5 mA/cm^2	7360	6409	12.92%

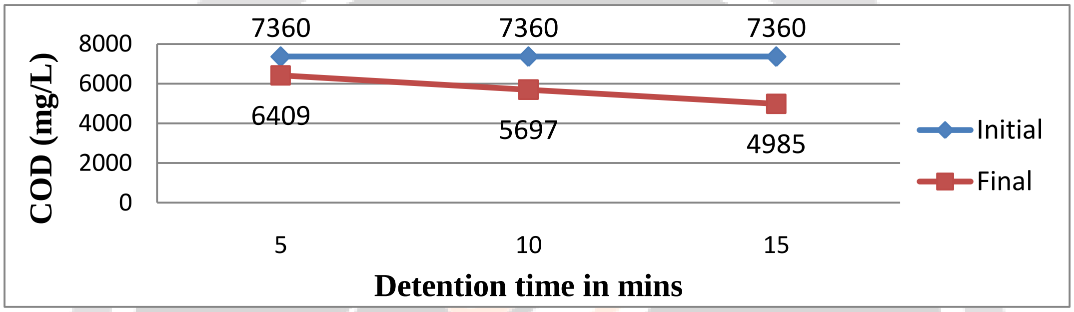


Chart 7: Performance of electrocoagulation on removal of COD for different current density

6.8 PERFORMANCE OF ELECTROCOAGULATION BY USING ALUMINUM ELECTRODE AS ANODE & GRAPHITE ELECTRODE AS CATHODE FOR DIFFERENT CURRENT DENSITY

Table 9: Performance of electrocoagulation on removal of COD for different current density

Parameter	Detention time	Current density	Initial (mg/L)	Final (mg/L)	% removal of COD
COD	10 mins	15 mA/cm^2	7360	5208	29.23%
	10 mins	10 mA/cm^2	7360	5952	19.13%
	10 mins	5 mA/cm^2	7360	6696	9.02%

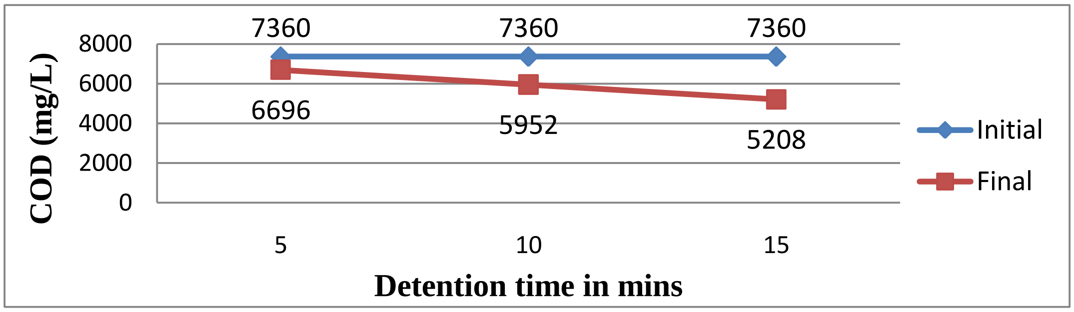


Chart 8: Performance of electrocoagulation on removal of COD for different current density

6.9 PERFORMANCE OF ELECTROCOAGULATION ON REMOVAL OF pH AT DIFFERENT DETENTION TIME

Table 10: Performance of electrocoagulation on removal of pH at different detention time

Parameter	Detention time	Initial	Final
pH	5	4.1	5.7
	10	4.1	6.8
	15	4.1	7.1
	20	4.1	7.06

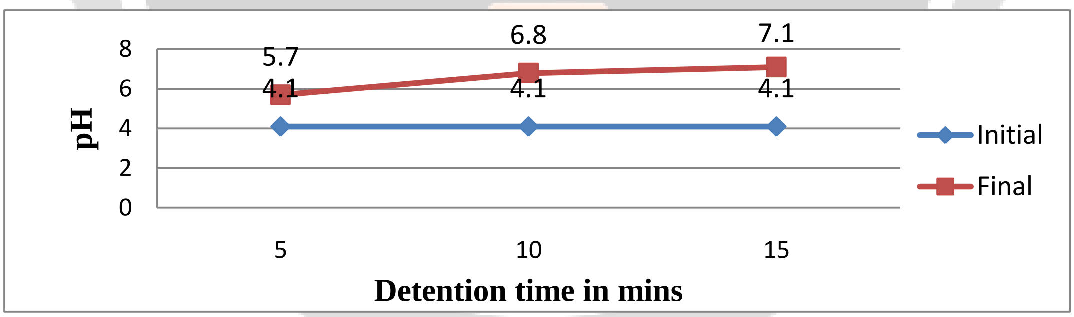


Chart 9: Performance of electrocoagulation on removal of pH at different detention time

7. CONCLUSIONS

This study confirmed that the electrocoagulation is highly effective on removing COD up to 78.21% from wastewater of 'Thalic Acid" manufacturing industry. Initially the pH of Dairy waste sample was more alkaline but due to the techniques implemented the pH was brought up much near to the neutral axis. Experiments shows that by using Iron electrode as anode & cathode the COD removal is higher than using Aluminum electrode or graphite electrode. So the treated waste can be discharged to the CETP for the further treatment. Hence, the electrocoagulation treatment may prove to be a handy solution for the chemical industry of manufacturing of 'Thalic Acid'..

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