# COMPARATIVE STUDY OF COPPER AND ALUMINIUM AS ELECTRODE IN THE TREATMENT OF SUGAR WASTEWATER

[1]Elamaran. E, [2]Panneerselvam.G,
[1]Post Graduate Student, [2] Professor & Head of the department
[1]Environmental Engineering, Department of civil engineering
[1]A.C Government College of Engineering and Technology, Karaikudi-630 003

**ABSTRACT:** Sugar industry is one of the major industries which have been included in the polluting industries list by the World Bank. Different pollution monitoring agencies like State and National Pollution Control Boards have been made compulsory for each industry to set up a waste water treatment plants. Sugar industry wastewater is characterized by high biochemical oxygen demand (BOD5), chemical oxygen demand (COD), and other pollution load. The purpose of this study is to investigate the effects of the operating parameters such as applied voltage, number of electrodes, and reaction time on a real Sugar wastewater in the electrocoagulation process. For this purpose copper and Aluminium electrodes were used. It has been shown that the removal efficiency of COD, BOD5, and TSS increased with increasing the reaction time. Copper Electrode having more efficiency removal than aluminium electrode. The results indicate that electrocoagulation is efficient and able to achieve 79.25% COD removal, 76.65% $BOD_5$ removal and 84% TSS removal at 6 V during 60 min at pH 6 in copper electrodes . Finally, the results demonstrated the technical feasibility of electrocoagulation process using Copper electrodes as a reliable technique for removal of pollutants from sugar wastewaters.

**KEYWORD:**
Sugar Wastewater, Electrocoagulation, Copper & Aluminum Electrodes, COD, $BOD_5$, TSS

## I.INTRODUCTION

### 1.1 Coagulation methods

There is a growth in demand for new water treatment technologies as the world's population increases and fresh water sources are polluted. Waterborne diseases are still common in developing countries due to the lack of funding or appropriate know for water purification. Industry also uses these limited water sources and has to acquiesce to lower quality raw water as a higher proportion of fresh water is required for human consumption. Wastewater treatment technologies used in both municipal and industrial applications have to be further developed in order to reduce the pollution of receiving water bodies. Chemical coagulation and flocculation are commonly used as a part of the water purification systems for the removal of pollutants from raw waters and wastewaters. Their main function is to enhance particle separation in the subsequent processes, such as filtration, sedimentation or flotation. In order to understand destabilization of particles by coagulants and flocculants, it is crucial to understand the mechanisms which stabilize particles in aqueous solutions. Chemical coagulation and flocculation are used in both industrial and municipal raw water and wastewater treatment systems. They can enhance the removal of several types of pollutants from the water streams. Typical examples of pollutants to be removed are BOD, COD and TSS. The most commonly used coagulants are aluminium or iron salts, such as Sulphates and chlorides. These metal salts form various hydrolysis products in the water depending on water chemistry, such as pH and the concentration of anions. Metal cations and hydroxides destabilize colloid pollutants in water by reducing repulsion forces between the colloids and by entrapping particles in the sludge. To prevent the macro flocs from shearing, careful attention is given to the mixing velocity and energy. The mixing velocity and energy are abated when there appear to be an increase in flocs formation.

### 1.2 Electrocoagulation methods

Electro coagulation (EC) also known as radio frequency diathermy or short wave electrolysis is fast becoming popular as an alternative method for the treatment of water and wastewater. The process is applied when removal of pollutant by chemical coagulation becomes difficult or impossible. EC is an advanced economical water treatment process that has been shown to be effective in removing suspended solids, depolluting heavy metals and breaking down emulsifiers. EC consists of pairs of sheet of metals used as electrodes (cathode and anode) and arranged using the principle of electrolysis DC. When the cathode electrode is immersed in the water or wastewater, the metal emits electrons which neutralize particles in the water by forming hydroxide complexes which agglomerates. Electrodes which initiate coagulation in the EC process are made up of metals such as Cu.

### 1.3 Mechanisam of Electrocoagulation

Electrocoagulation (EC) is a process which depends on responses of water contaminants to strong electric fields and electrically induced oxidation and reduction reactions. EC technique utilizes direct current to cause sacrificial electrode ions to remove undesirable contaminants either by chemical reaction and precipitation or by causing colloidal materials to coalesce and then they are removed by electrolytic flotation. During EC, coagulants are obtained *in situ* by the dissolution of the anode. In this process if M is considered as anode, the following reaction will occur.

**At the anode:**

$M(S) \rightarrow Mn+ (aq)+ne-$

$2H2O(l) \rightarrow 4H+ (aq)+ O2(g) + 4e-$

**At the cathode:**

$Mn+ (aq)+ ne- \rightarrow M(S)$

$2H2O(l)+2e- \rightarrow H2(g)+2OH- 3$

Freshly formed amorphous Mn (OH)3 has large surface areas that are beneficial for rapid adsorption of soluble organic compounds and trapping of colloidal particles.

### 1.4 Sugar Industry Wastewater

Sugarcane has been cultivated from pre-historic times in India. Indian mythology supports the fact as second largest producer of sugarcane next to Brazil. Sugar industry is seasonal in nature and operates 150–180 days in a year . A significant large amount of waste are generated during the manufacture of sugar, which contains a high amount of pollutants in terms of suspended solids, organic matters, biological and chemical oxygen demand effluent including sludge, press mud and bagasse . At present 526 sugar mill are operating in India that produced 33.69 million tons of sugarcane in the year of 2016-17 . To crush one tone of sugarcane nearly 2000 l water required, which generated nearly 1000 l of wastewater . Several methods has been suggested by authors to treat the sugar industry wastewater like adsorbent , electrochemical , anaerobic biological treatment , biochemical oxidation , etc. The wastewaters treated by above methods are not meeting the discharge limit; it required modification either in individual treatment or separately. Some author has been reported the combination like electrocoagulation and membrane technology, thermolysis and coagulation , electrocoagulation and coagulation etc. The combined technology is better alternative to bring the wastewater into discharge limit. Electrocoagulation has its own impression to treat the various wastewater like textile industry wastewater , electroplating industry wastewater , Dyes , dairy wastewater etc. The electrocoagulation technology possesses many advantages viz. in situ production of coagulants (less external chemicals), easier installation, lower secondary pollution, odor and color removal and lower residence times . It is complex process with a multitude of mechanisms operating synergistically to remove pollutants from the water. Electrocoagulation treatment methods offer an alternative to the use of metal salts or polymers and polyelectrolyte addition for breaking stable emulsions and suspensions. The destabilization mechanism of the contaminants, particulate suspension, and breaking of emulsions taking place in an EC reactor may be summarized Liu et al . As a EC suitable anode materials iron , aluminum and other metals like carbon , mild steel , copper and stainless steel as well as combination of iron and aluminum are used for treatment of different industrial waste water. Up to till now no author has been reported to treat the sugar industry waste water by using copper and aluminium as electrode in electrocoagulation process. So the investigations have been done to treat the sugar industry wastewater by copper and aluminium metal by electrocoagulation process. The parameters namely pH, electrode distance, current density, mass loading has been reported. The process generates sludge that necessitates a need of post treatment by separation; hence its separation by settling and filtration was also studied.

## 2.LITERATURE REVIEW

**Anurag Tiwari, Omprakash Sahu.,[1]** conducted In treatment system, single treatments of effluent are not effective to manage the dischargeable limit. So an attempted has been made to treat sugar industry wastewater with electrochemical and chemical process by using copper as electrode and chemical. Electrochemical process shows 81% chemical oxygen demand and 83.5% color reduction at pH 6, electrode distance 20 mm, current density 178 A $m^{-2}$ and 120 min treatment time. The combined treatment results show 98% chemical oxygen demand and 99.5% color removal at 8 mM mass loading and pH 6 with copper sulphate.

**C.Barrera-Diaz.,[2]** evaluates the use of aluminum contained in the aluminum-polyethylene films as anodic electrodes using the electrocoagulation technique to reduce the pollutants contents of an industrial wastewater quickly and effectively. Two different current densities were applied 25 and 12.5 mA cm-2. When the current density of 25 mA cm-2 is used, the aluminum electrodes reduce the COD of wastewater by about 65% and the aluminum-polyethylene films electrodes reduces the COD by 56%. The color and turbidity reductions are 87 and 90% respectively. The use of aluminum-polyethylene films as electrodes in the electrocoagulation process contributes to the pollutant removal without the addition of chemical reagents or changing the pH, so it is both effective and environmentally friendly.

**Claudio Escobara et al., [3]** conducted Chemical, electrochemical and flow variables were optimized to examine the effectiveness of the electrocoagulation process for the removal of copper, lead and cadmium. The electrochemical process, which uses electrodes of commercial laminate steel, was applied to simulated wastewater containing 12mgdm3 of copper, 4mg dm3 of lead and 4mg dm3 of cadmium. The optimum conditions for the process were identified as pH ¼ 7, flow rate ¼ 6.3 cm3 min1 and a current density between 31 and 54Am2. When the electrode geometric area and time of electrolysis reached critical values, the copper removal reached a maximum value of 80%. A linear relationship was identified between the current density and the mass of generated sludge. In addition, a linear relationship was found between specific energy consumption and current density. The results of this investigation provide important data for the development of an industrial – scale electrolytic reactor.

**Gerson de Freitas Silva Valente et al., [4]** research deals with the investigation of electrocoagulation (EC) treatment of wastewater from a dairy plant using aluminum. Electrolysis time, pH, current density and distance between electrodes were considered to assess the removal efficiency of chemical oxygen demand (COD), total solids (TS) and their fractions and turbidity. Samples were collected from the effluent of a dairy plant using a sampling methodology proportional to the flow. The treatments were applied according to design factorial of half fraction with two levels of treatments and 3 repetitions at the central point. The optimization of parameters for treating dairy industry effluent by electrocoagulation using aluminum electrodes showed that electric current application for 21 minutes, an initial sample pH near 5.0 and a current density of 61.6A m-2 resulted in a significant reduction in COD by 57%; removal of turbidity by 99%,removal of total suspended solids by 92% and volatile suspended solids by 97%; and a final treated effluent pH of approximately 10. Optimum operating condition was used for cost calculations show that operation cost is approximately 3.48R$ m-3.

**Gouri Mirji, P.B.Kalburgi [5]** conducted a study of electrocoagulation mechanism was used to remove chemical oxygen demand of dairy wastewater. In the process, the effects of initial pH, electrolysis time, voltage were examined. The optimum operating range for each operating variable was experimentally determined. The greatest removal efficiency was obtained with the use of aluminum as anode and iron as cathode (Al–Fe system).With this latest system, optimal values of voltage, initial pH, boric acid concentration and electrolysis time were 8V, 7.0, 5 g/L and 30 min respectively. The batch experimental results revealed that COD in aqueous phase was effectively removed. The overall COD removal efficiencies reached 88.54%.

**G. Mouedhen et al., [6]** conducted in the present work, electrocoagulation process with aluminum electrodes was investigated. Different operational conditions such as composition of Na2SO4 based solutions, pH and current density were examined in a systematic manner. Their influence on (i) electrode polarization phenomena, (ii) pH evolution during electrolysis and (iii) the amount of Al released (coagulant) was investigated. For this purpose, potentio dynamic tests and electrolysis using different electrochemical cell configurations were conducted. It is mainly found that (i) a minimum Cl−concentration of the electrolyte of about 60 ppm is required to breakdown the anodic passive film and considerably reduce the cell voltage during electrolysis; (ii) the anodic dissolution efficiency is unit; (iii) the global amount of coagulant Al3+ generated has two origins: electrochemical oxidation of the anode and "chemical" attack of the cathode and (iv) electrolysis with Al electrodes acts as pH neutralization of the electrolytic medium. Taking into account advantage of the pH evolution observed during electrolysis, electrocoagulation tests were performed to treat a synthetic wastewater containing heavy metallic ions (Ni2+ , Cu2+, Zn2+). Removal efficiencies over 98% were reached. Furthermore, our results displayed prominently that an increase of current density notably reduces the treatment duration without inducing a strong increase of the charge loading.

**Namrata S Gajjar and MsNeha Patel [7]** conducted treatment of paint industry (emulsion) wastewaters by electrocoagulation using different electrode materials has been investigated in this paper. Several working parameters, such as pH, current density, operating time, types of electrodes and surface area were studied in an attempt to achieve a higher COD removal capacity. The electrolytic cell used was a 500 ml cylinder glass reactor with working volume 400 ml and equipped by magnetic stirrer without temperature control. The DC power supply was controlled by a voltmeter. The study also revealed that electrocoagulation with Al electrodes was more effective than MS and SS electrode.

**S. Aoudj et al., [8]** conducted In the present work, electrocoagulation was applied for the color removal of solutions containing Direct red 81. Experiments were performed for synthetic solutions in batch mode. The study focuses on the effect of following operational parameters: electrolysis time, current density, initial pH, inter-electrode distance, initial dye concentration and type of supporting electrolyte. The obtained results showed that decolouration optimal conditions are the following: initial pH of about 6, current density of 1.875mA/cm2, inter-electrode distance of 1.5cm and finally the use of NaCl as supporting electrolyte. In best conditions, high decolouration efficiency was obtained, reaching more than 98% of colour removal. Fourier transform infrared spectroscopy (FTIR) analysis was used to characterize the residual EC byproduct with and without the presence of dye.

**Yavuz Demirci.,[9]** This paper presents the results of the treatment of a real textile wastewater by electrocoagulation (EC) process. The textile effluent used in the experiments was obtained from a textile industry in Malatya/Turkey. The effluent was wastewater taken from dying process of the industry. Aluminum electrodes were connected to an EC reactor in three different types: monopolar-parallel (MP-P), monopolar-serial (MP-S), and bipolar-parallel (BP-P). Color and turbidity removals were selected as performance criteria. Moreover, the financial cost of the total treatment has been considered as important as removal efficiencies. Electrical and sacrificial electrode costs have been used in the calculation of the total cost. The results show that MP-P mode is the most cost effective for both electrode connection types. All connection types show similar results in reducing color and turbidity, MP-P is preferred as a low cost treatment. In addition, iron and aluminum electrode materials have been investigated in the MP-P EC reactor. The results show that, according to electrical and sacrificial electrode costs, iron is superior to aluminum but aluminum electrode leads to high turbidity, color and COD removal efficiencies.

## 3.EXPERIMENTAL STUDIES :

### 3.1. MATERIALS

All the laboratory grades chemical (Sodium Hydroxide, Hydrochloric acid, poly aluminum chloride and Copper Sulphate) were used for analysis. The copper and Aluminium sheet was purchased from market and used as electrode. The waste water collected from E.I.D Parry (India) Limited ,Kurumbur , Aranthangi , Pudukkottai, Tamil Nadu – 614622, India and preserved at 18 °C until used.

### 3.2. EXPERIMENTAL METHODS

The electrocoagulation experiment was performed in electrochemical of (10.7×10.7×13.7 cm) capacities. The reactor fitted with squared electrode having dimension 7.5 cm x 7.5 cmx 1 mm of copper and aluminium material. A space of 1 cm was varies between to two electrodes and 1.5 cm gap was maintained at the bottom of the reactor for the movement of magnetic stirrer. A DC power in range of 6 (V) voltages and 2(A) current was supplied to respective terminals in parallel arrangement. At fixed variable time measure amount of treated was collected for analysis. Then waste water sample was kept for settling (2 h). Clean liquid was collected and analyses for COD , BOD and TSS removal. The percentage removal of COD , BOD and TSS was calculated by Eq. (1). The experimental setup for treatment of sugar industry waste water is shown in Fig. 1.

$$\text{Removal}(\%) = (c_i - c_f) x 100 \div c_i \quad (1)$$

Where

$c_i$ = Initial concentration (mg/l)

$c_f$ = Final concentration (after treated mg/l)

**(a)**

**(b)**

**Fig.1.:(a)Experimental setup (b) Treated water**

**TABLE 1: Characteristics of the raw sugar wastewater used for this study**

| S.No | Characteristics | Quality |
|---|---|---|
| 1 | color | Dark brown |
| 2 | pH | 6.78 |
| 3 | Electrical Conductivity | 0.45 mmho/cm |
| 4 | COD | 3900 (mg/l) |
| 5 | $BOD_5$ | 2100 (mg/l) |
| 6 | TotalSuspended Solids | 950 (mg/l) |
| 7 | Total Dissolved Solids | 1880 (mg/l) |

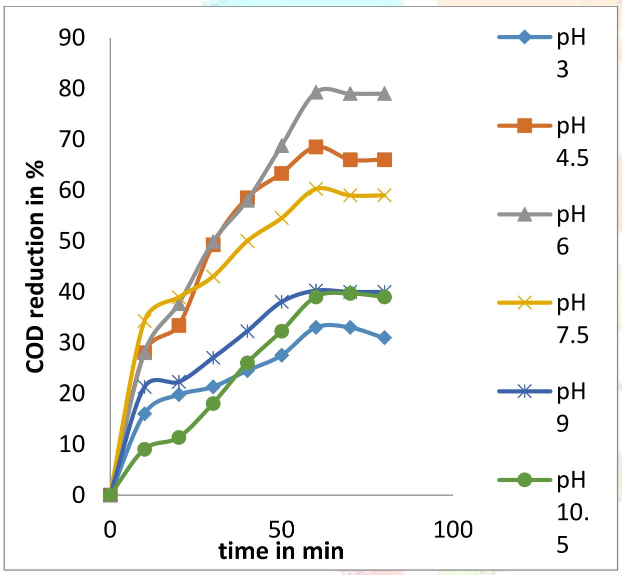
## 4.RESULT AND DISCUSSION

### 4.1 EFFECT OF pH

The effect of initial pH was carried out from pH 3–10.5 at electrode distance (ED) 10 mm, current density (CD) 2 A and time (t) 80 min. Four copper and Aluminium electrodes configuration on percentage COD , $BOD_5$ and TSS reduction is presented in Fig. 2,3&4 (a) and (b) respectively. Copper Electrode having more efficient removal than aluminium electrode. So that in copper Electrode it can seen that COD 33%, 68.50%, 79.25% , $BOD_5$ 32%, 67.75%, 76.65% and TSS 40.25, 76, 84 removal was increases with increased in pH 3, 4.5 and 6. Further increase in pH 7.5, 9 and 10.5, COD 60.25%, 40.25%, 39% , $BOD_5$ 56.60%, 33.5%, 36% and TSS 72.5, 55, 49.25 removal was decreases at 60 min of reaction time. The lower percentage of COD, $BOD_5$, TSS removal can be explained by amphoteric behavior of $Cu(OH)3$, which does not precipitated at high acidic and alkaline pH.

**4.2 REMOVAL EFFICIENCY OF COD BY USING COPPER AND ALUMINIUM AS ELECTRODES**

**(a)**




**(b)**

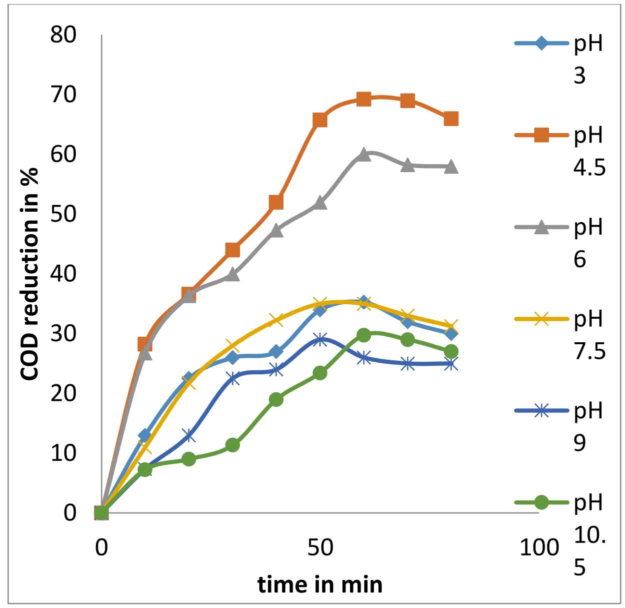
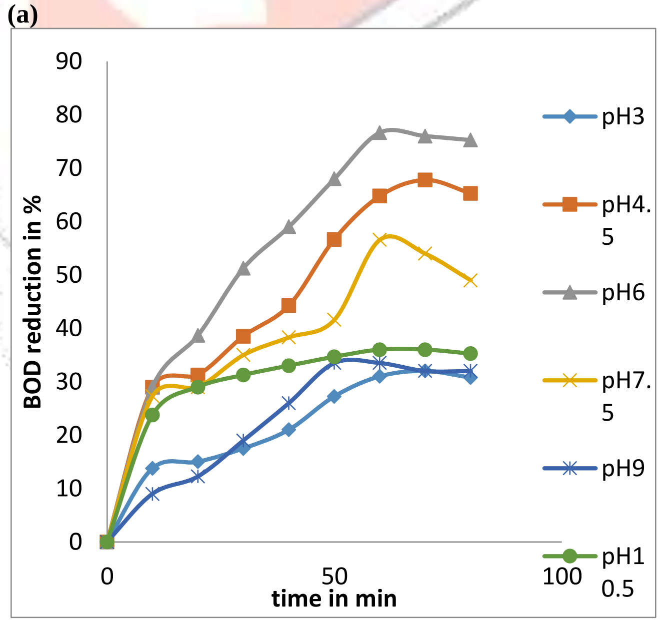



**Fig 2: Effect of initial ph on COD removal (a) copper (b) aluminium electrode at ED =10mm, CD= 2A, COD=3900 (mg/l)**

**4.3. REMOVAL EFFICIENCY OF BOD BY USING COPPER AND ALUMINIUM AS ELECTRODES**

**(a)**




**(b)**

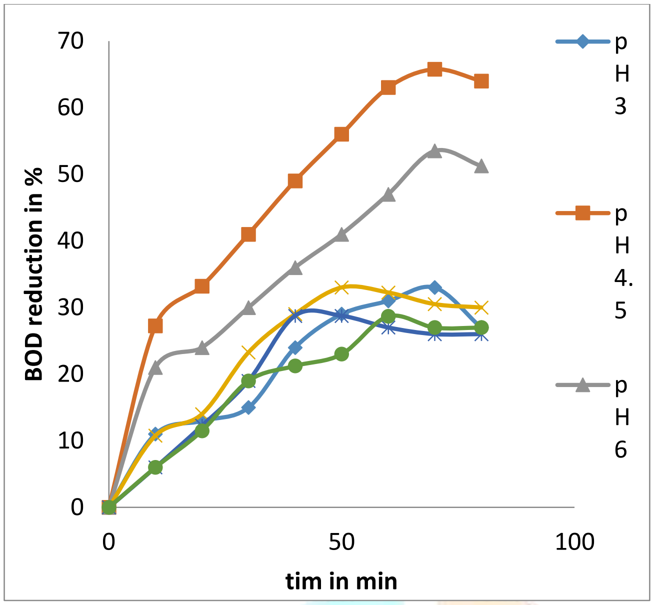
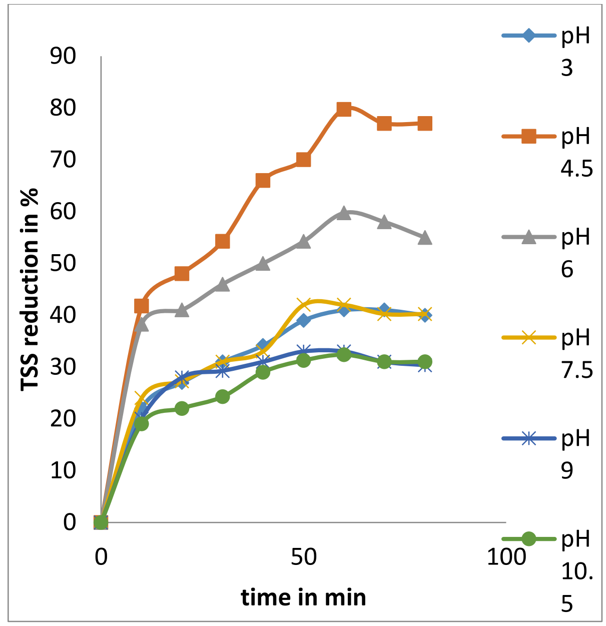



**Fig 3: Effect of initial ph on BOD removal (a) copper (b) aluminium electrode at ED =10mm, CD= 2A, BOD=2100 (mg/l)**

### 4.4. REMOVAL EFFICIENCY OF TSS BY USING COPPER AND ALUMINIUM AS ELECTRODES

**(a)**




**(b)**

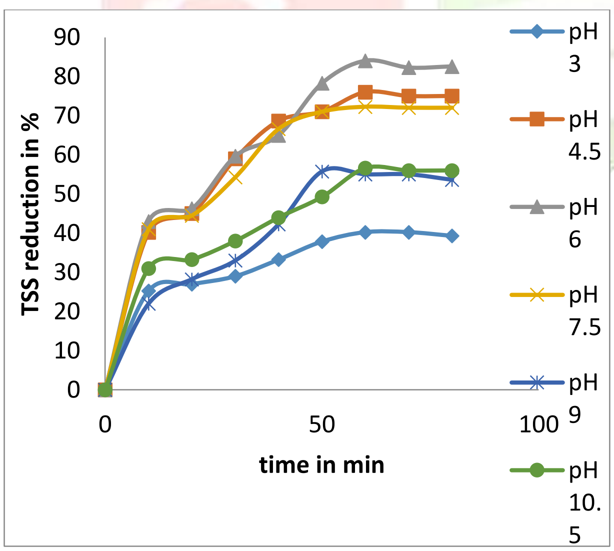



**Fig 4: Effect of initial ph on TSS removal (a) copper (b) aluminium electrode at ED =10mm, CD= 2A, TSS=950 (mg/l)**

**TABLE 2: Analysis of residue obtained after Electrocoagulation (Copper) at different pH**

| S.No | Parameter/ pH | 3 | 4.5 | 6 | 7.5 | 9 | 10`5 |
|---|---|---|---|---|---|---|---|
| 1 | COD | 33 | 68.50 | 79.25 | 56 | 40.25 | 39.65 |
| 2 | $BOD_5$ | 32 | 67.75 | 76.65 | 60 | 33.5 | 36 |
| 3 | TSS | 40.25 | 76 | 84 | 72 | 55.75 | 56.60 |

**TABLE 3: Analysis of residue obtained after Electrocoagulation (Aluminium) at different pH**

| S.No | Parameter/ pH | 3 | 4.5 | 6 | 7.5 | 9 | 10`5 |
|---|---|---|---|---|---|---|---|
| 1 | COD | 35.25 | 68.75 | 60 | 35 | 29 | 28.68 |
| 2 | $BOD_5$ | 33 | 69.25 | 53.50 | 33 | 28.75 | 29.75 |
| 3 | TSS | 41 | 79.7 | 59.7 | 42 | 33 | 32.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | 5 | 5 | | | 5 |

**5.SUMMARY AND CONCLUSION**

The influence of various experimental parameters such as applied voltage and electrolysis time on the removal of pollutants from sugar wastewater was studied. The results of this study have shown the applicability of electrocoagulation in the treatment of real sugar industry wastewater. The treatment rate is show to applied voltage and reaction time. Indeed, the 4 voltage produced the quickest treatment with an effective reduction of COD, $BOD_5$, and TSS. Consequently, it can be inferred that electrocoagulation is a comparatively suitable process for removal of COD, $BOD_5$, and TSS other pollutants using copper &aluminium electrodes to effectively treat sugar industry wastewater.

According to the obtained results, the following can be concluded: The optimization of parameters for the treatment of sugar industry effluents, using copper electrodes in the process of electrocoagulation, showed that higer efficient than aluminium electrode an electric current applied for 80 minutes, with a sample with an initial pH close to 6.0 shows a significant reduction in COD by 79.25%, $BOD_5$ by 76.65%, TSS by 84%. Sugar wastewaters are generally treated usually using biological methods such as activated sludge process, aerated lagoons, aerobic bioreactor. Aerobic biological processes are high energy intensive, whereas anaerobic treatment of sugar wastewater reflects very poor nutrient removal, and effluents treated by anaerobic biological processes need additional treatment. This study shows that electrocoagulation treatment would be used with biological process. Electrocoagulation process is beneficial for removal of COD, $BOD_5$ and TSS.

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