Treatment of hospital wastewater by using electro-chemical coagulation

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Abstract

The main goal of this study was to determine of the removal efficiency of chemical oxygen demand (COD) from educational hospital waste-water using electrocoagulation process by using 2 aluminium and stainless-steel electrodes. A laboratory-scale batch reactor was conducted to determine the removal efficiency by the electrocoagulation method. Samples of Alva's health center Hospital waste-water was collected according to standard methods. The removal of COD from the waste-water was determined and the voltage range of 12, 18, and 24 V at the operation time of 15, 30, 45, and 60 min. Data were analyzed and relation between these parameters. Results: The removal efficiency is increased by 93.2% at the optimal condition of 24 V- and 60-min operation time. By increasing the reaction time from 15, 30, 45 and 60 min at voltages (12, 18, and 24 V), the removal efficiency was increased from 73.3%, 77.7%, 87.1%and 93.2%. The maximum COD removal efficiency was observed at 24 V- and 60-min reaction time using four 2 aluminium and 2 stainless steel electrodes. Analysis showed a significant relationship between voltage and the reaction time with the removal efficiencies. Due to the high efficiency of the electrocoagulation process and also the simplicity and relatively low-cost, it can be used for removing COD from hospital waste-water.

***Keywords**-Electro-chemical coagulation, chemical oxygen demand, Hospital wastewater*

INTRODUCTION

Hospital waste-water is one of the most dangerous types of pollution. These waste-waters are contaminated with pathogens, such as bacteria, viruses, and parasites, as well as hazardous chemical compounds, pharmaceutical compounds, and radioactive isotopes. Protection of water resources in a country like India, which has many climatic constraints, is very important.

In general, the most important goals of waste-water treatment are controlling the pollution, preventing the infectious, and chronic diseases, protecting the environment, and reusing the waste-water.[2] Hospital waste-water contains a large number of pathogens and this reveals the importance of the sources of pollutants. In case hospital waste-water is properly treated, it can be reused for agricultural purposes.[3] Electrical coagulation is a process of waste-water treatment by electrochemical method through, which direct current electricity is used in order to remove the contaminants from the solution. In this process, a coagulant is produced in place through electrolytic oxidation of an anode which is made of appropriate materials. Then, charged ionic species are removed by allowing the reaction to the opposite charge or the metal hydroxides produced within the waste.[4]

Recently, the electrocoagulation technology is highly acceptable for waste-water treatment, due to the need for simple and easy operation, good settling ability of the sludge, lower sludge production, bigger produced flocks compared to the chemical treatment, and reducing the secondary pollution by not using the chemical compounds and also being economic, safe and environmentally friendly.[5-8] The other capability of this process is the removal of contaminants, such as heavy metals. For instance, it is utilized for the removal of chromium, colloidal and suspended solids, fat, oil, grease, organic compounds, bacteria, viruses, cysts, and dye mono-azo acid red from aqueous environment.[5-13] Electrocoagulation process is suitable for a wide variety of waste-water treatment plants, such as dairy products,[14] removal of cyanide, biochemical oxygen demand, and chemical oxygen demand (COD) from olive oil waste-water[11] and removal of detergent from industrial waste-water of automobile industry.[15] The results showed an increase in the removal of dexamethasone (up to 38.1%) with a rise of the current applied and a decrease of the electrode distance, in aqueous solutions.[16] Bazrafshan et al. indicated that electrocoagulation process is able to remove COD from real dairy waste-water up to 98.84% at 60 V during the

60 min operation.[17] The maximum COD removal efficiency was measured 82% at 100 mg/l dye concentration by electrocoagulation.[18] The removal of COD from cardboard paper mill effluents was investigated using aluminium and iron electrodes. The maximum removal efficiencies of COD under optimal operating conditions (pH = 5.29 for Al electrode and pH = 7.21 for Fe electrode) with a current density of 4.41 mA/cm2 and operating time of 10 min were 99.93% and 99.92% for Al and Fe electrode, respectively.[19] The removal of heavy metals and COD from real industrial waste-water were investigated by electrocoagulation. COD was removed up to 83.94% and 53.83% by Al and Fe electrodes, respectively.[20]

In cities with a sewage collection system, it is possible to dispose the hospital waste-water to the networks, however, if a city has no sewage collection systems, complete hospital waste-water treatment must be provided. Conventional waste-water treatment plants are not able to meet the effluent quality standards for the hospital waste-water effluent. Although the electrocoagulation process has been used for the treatment of many synthetic waste-waters, so far this method has not been used for the treatment of hospital waste-water. Furthermore, the effect of interfering compounds presents in the real waste-water has been intensively studied using the electrocoagulation method. Therefore, the objective of this study was to

i. Evaluate the feasibility of using the electrocoagulation process for the treatment of Alva's health centre hospital waste-water and

ii. ii. Determine the optimal condition for maximum COD removal efficiency.

MATERIALS AND METHODS

All the tests were performed at a batch reactor mode at room temperature and normal pressure. The study was conducted in a laboratory scale using two-fold and four-fold stainless-steel and aluminium electrodes [Figure 1]. An electrochemical cell made of 10 mm thickness glass and 1.5l volume with dimensions of 14 cm × 10.2 cm × 13 cm and stainless-steel and aluminium plate with dimensions of 8 cm × 8 cm × 1 mm was used as the electrode. The electrodes were vertically separated by 1 cm from each other. The end of each electrode was connected to a direct current (DC) power supply. Table 1 summarized the characteristics were used for the removal of COD from Alva's health centre hospital waste-water using the electrocoagulation method. The mixing was performed by a magnetic stirrer at a constant speed of 300 rpm. Control was also used for this study to decrease the effect of volatile organic content in the waste-water.

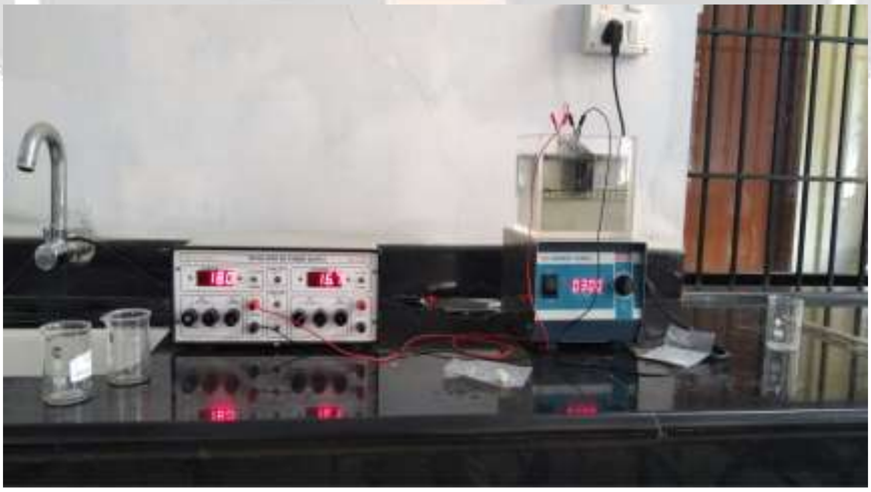

Figure 1: The Schematic design of electrocoagulation

All chemicals were purchased from Sri Durga laboratory equipment supplies Mangalore. Sand paper was used to clean the electrodes before starting the experiment.

The hospital used in this study is one of the largest hospitals in Moodbidri province, which includes 300 beds and 10 wards. The volume of the sewage produced by the hospital is over 1000 m3/day. The extended aeration activated sludge is used to treat the waste-water which is not efficient in removing COD. 48 samples of Alva's health centre hospital waste-water in Moodbidri were collected for the periods of 1 months according to standard methods.[21] The waste-water characteristics such as COD, phosphate, nitrate, and turbidity were measured.[21]

Data regarding the chemical and physical properties of the waste-water sample were summarized in Table 2. The effects of different parameters (voltage, reaction time, and electrode type) on the reduction rate of COD (48 samples) were determined at four replications. All the data were presented based on the mean. In this research, influent wastewater samples were studied in order to determine the optimal conditions. The studied parameters were electrode materials (aluminium and stainless-steel) with the arrangement of stainless steel-stainless steel, aluminium-aluminium, aluminium-stainless steel and stainless steel- aluminium the number of electrodes (2 and 4 electrodes), operation time (15, 30, 45, and 60 min), voltage (12, 18, and 24 V) and the current intensity between 0.09 and 0.31 amperes. The effect of distance between two electrodes (1cm) was also investigated. All the experiments were done in four replicates. In each set of experiments, the samples were taken from the reactor and COD, TDS and TSS was determined using the titration method according to the standard method.[16] Moreover, nitrate and phosphate were measured by a spectrophotometer according to the standard method respectively.

The optimal conditions of different parameters were determined according to COD value and the data were analysed.

Table 1: Characteristics used for the removal of COD from Alva's health centre hospital waste-water using the electrocoagulation method.

Reactor characteristics	
Length (mm)	140
Width (mm)	102
Height (mm)	130
Reactor dimensions	
Thickness (mm)	10
Volume (L)	1.5
Free board (cm)	3
Electrode dimensions	
Length (mm)	80
Width (mm)	80
Thickness (mm)	1

Table 2: The chemical and physical properties of Alva's health centre hospital waste-water using the electrocoagulation method.

Test	Unit	Result
pH	-	8.1
COD	mg/l	9000
Phosphate	mg/l	26.5
Nitrate	mg/l	0.117

RESULTS

According to studies conducted on wastewater a voltage and operation time were selected in the range of voltage of 12, 18 and 24 V and the operation time of 15, 30, 45, and 60 min respectively. Since, the study was conducted on the hospital wastewater, the fluctuation of COD was observed during the period of 1 months sampling of waste-water. First of all, the optimal voltage to achieve the maximum COD removal efficiency from Alva's health centre waste-water was determined. According to Figure 2, COD removal efficiency during the electrocoagulation process using four stainless steel electrodes at 60 min operation time and the voltages of 12, 18, and 24 V were 68.8%, 77.4%,86% respectively. COD removal efficiency was increased by increasing the voltage. The same trend was seen by increasing operation time as well. The maximum removal efficiency at the applied voltage of 24 V at 60 min operation time was 86%.

According to Figure 3, COD removal efficiency during the electrocoagulation process using four aluminium electrodes at 60 min operation time and the voltages of 12, 18, and 24 V were 51.1%, 73.3%, and 82.2% respectively. COD removal efficiency was increased by increasing the voltage. The same trend was seen by increasing operation time as well. The maximum removal efficiency at the applied voltage of 24V at 60 min operation time was 82.2%.

According to Figure 4, COD removal efficiency during the electrocoagulation process using two pairs of aluminium- stainless steel at 60 min operation time and the voltages of 12, 18, and 24 V were 82.2%, 91.1%, and 93.3% respectively. COD removal efficiency was increased by increasing the voltage. The same trend was seen by increasing operation time as well. The maximum removal efficiency at the applied voltage of 24 V at 60 min operation time was 93.3%.

According to Figure 5, COD removal efficiency during the electrocoagulation process using two pairs of stainless steel-aluminium electrodes at 60 min operation time and the voltages of 12, 18, and 24 V were 55.4%, 60%, and 77.7% respectively. COD removal efficiency was increased by increasing the voltage. The same trend was seen by increasing operation time as well. The maximum removal efficiency at the applied voltage of 24 V at 60 min operation time was 77.7%.

The results indicated that by increasing the operation time the removal efficiency was increased. The maximum COD removal efficiency of 93.3% was achieved using 2 pairs of aluminium-stainless steel electrodes and the operation time of 60 min, whereas the minimum COD removal efficiency of 51.1% was achieved using four aluminium electrodes and the operation time of 15 min. The removal efficiencies of TDS, TSS, Hardness, Phosphate and Nitrate were 71.42%, 66.72%, 81.9%, 96.42% and 90.32% respectively.

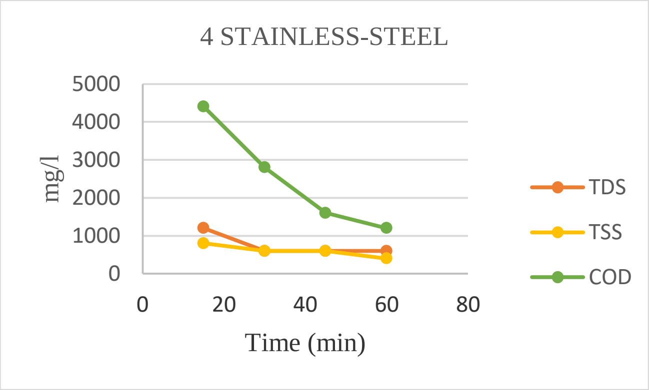

Figure 2: The reduction of chemical oxygen demand, TDS and TSS versus time during electrocoagulation process using four stainless-steel electrodes at optimal voltage 24V.

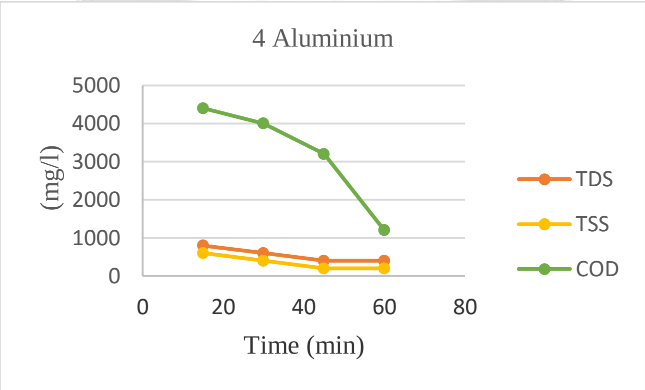

Figure 3: The reduction of chemical oxygen demand, TDS and TSS versus time during electrocoagulation process using four aluminum electrodes at optimal voltage 24V.

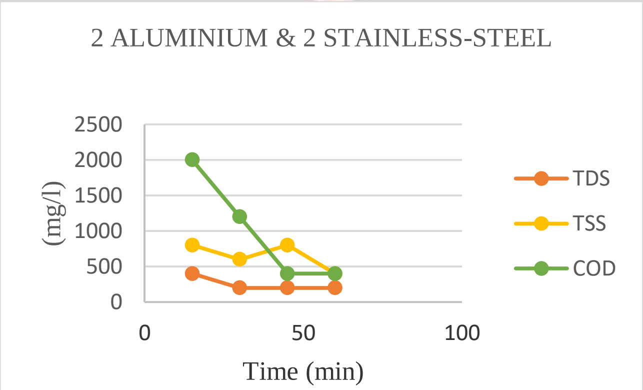

Figure 4: The reduction of chemical oxygen demand, TDS and TSS versus time during electrocoagulation process using two pairs of aluminum and stainless-steel electrodes at optimal voltage 24V.

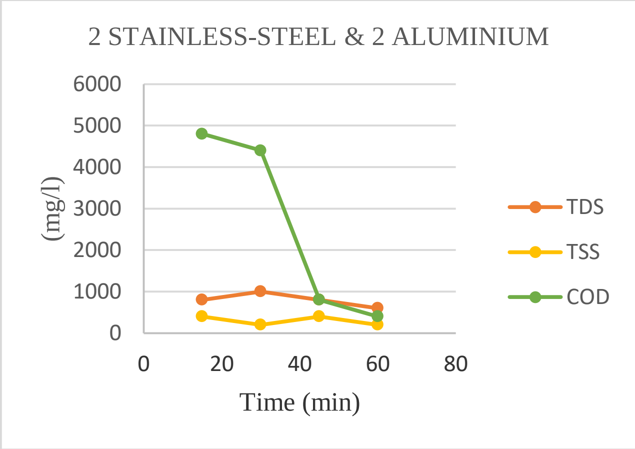

Figure 5: The reduction of chemical oxygen demand, TDS and TSS versus time during electrocoagulation process using two pairs of stainless-steel and aluminium electrodes at optimal voltage 24V.

DISCUSSION

Rahmani's studies also declared that the COD removal efficiency is increased by increasing the voltage.[22] By increasing the applied voltage, the current density is increased between the electrodes. Since the rate of electron flow is increased, the productions of ionic metals are accelerated and therefore the rate of the electrocoagulation process was enhanced.

In addition, the number of pairs of electrodes used in the electrocoagulation process has a large effect on the rate of COD removal efficiency. In fact, two pairs of electrodes result in a much greater removal efficiency compared to one pair of electrodes. On the other hand, the electrode material is also an important parameter affect the removal efficiency. The maximum removal is achieved using pair of stainless steel-aluminium electrodes. The comparison of the results obtained in this work demonstrated that the orders of the removal efficiencies are as follows: aluminium-stainless steel electrodes > stainless steel-aluminium electrodes > aluminium-aluminium electrodes > stainless steel-stainless steel electrodes.

According to the results of this study, there is a significant relationship between voltage and the COD removal efficiency, i.e., the COD removal efficiency decreased with increasing voltage from 12 to 24. The same results were obtained by other studies which revealed that the removal efficiency of pollutant had an inverse relationship with increasing voltage.[23]

Increasing the operation time had a major role in the performance of the electrocoagulation process. There are many electrochemical reactions occurring simultaneously at the anodes and cathodes. The main reaction is the destabilization of pollutants. Electrodes which produce coagulants into water are made from either stainless-steel or aluminium. Stainless steel and aluminium ions dissolve from the anodes. Released ions neutralized the charged particles and hence, the electrocoagulation process was performed. The removal efficiency was directly related to the concentration of ions generated on the electrodes. The ions concentration increased with increasing the time of electrolysis which in turn caused hydroxide flocks to increase. The results showed that the highest COD removal efficiency occurred at the operation time of 60 min. The effect of electrolysis time has been also considered as the main parameter in other studies. Many different studies demonstrated that increasing the electrolysis time resulted higher removal efficiency of COD, colour, heavy metals and phosphate. [22-25]

The results showed that the electrode material had affected COD removal efficiency. Using optimal condition (voltage of 24 V and operation time of 60 min), the removal efficiency of COD decreased from 93.3% (two pairs of aluminium -stainless steel to 77.7% (two pairs of stainless steel-aluminium electrodes). The results exhibited the same trend for two electrode pairs, i.e., the highest removal was obtained using stainless steel-aluminium electrodes, whereas the lowest removal related to stainless steel-stainless steel electrodes. This study showed that the maximum COD removal rate was associated with stainless steel-aluminium electrodes.

Since, economic evaluation is an important parameter in selecting an appropriate process for waste-water treatment; optimization was performed regarding electrical energy consumption. It can be concluded that the energy consumption rate with stainless steel-aluminium electrodes was more economical. Operating cost calculations have been made in a few articles. Calculations typically include the cost of chemicals, electrodes and energy. Many studies showed that the cost of electrocoagulation was much cheaper than chemical precipitation. A comparative study showed that electrocoagulation was faster and more economic, consumed less material and produced less sludge than chemical coagulation for COD removals. According to the results of this study, electrocoagulation can be an economically viable solution for the removal of COD from hospital waste-water. [27-30]

In conclusion, operating system parameters at the optimal condition can provide the COD removal efficiency of more than 96.56%. The results indicated the effectiveness of electrocoagulation for the treatment of hospital waste-waters. Moreover, data obtained in the present study demonstrated the technical feasibility of the electrocoagulation process using stainless steel-aluminium electrodes as a reliable method for the removal of COD from hospital waste-water. Due to the high efficiency of the electrocoagulation process and also the simplicity and relatively low cost, it might be considered as a reliable, flexible, fast, effective, and economical method for hospital waste-water treatment.

CONCLUSION

In conclusion, operating system parameters at the optimal condition can provide the COD removal efficiency of more than 93.3%. The results indicated the effectiveness of electrocoagulation for the treatment of hospital waste-waters. Moreover, data obtained in the present study demonstrated the technical feasibility of the electrocoagulation process using 2 aluminium and 2 stainless steel electrodes as a reliable method for the removal of COD from hospital waste-water. Due to the high efficiency of the electrocoagulation process and also the simplicity and relatively low cost, it might be considered as a reliable, flexible, fast, effective, and economical method for hospital waste-water treatment.

The study provides:

- The performance for electrocoagulation treatment of hospital wastewater was studied focusing on the influence of operating condition (current, electrocoagulation time and pH).

- The statistical analysis shows that all the variables used in the preparation of model for the treatment of hospital waste water are within the boundaries and have a significant effect on the model.

- Current, electrocoagulation time and pH for the treatment of hospital wastewater influence the COD removal and electrode Consumption The optimized operating condition for the maximum removal of COD and minimum electrode consumption and 2 aluminium and 2 stainless steel electrodes, electrocoagulation time (60 minutes).

- The actual COD removal and electrode consumption at optimized conditions are 93.3%. hence, the results of this study show that electrocoagulation is an effective method for treatment of Hospital wastewater.

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