# Electrocoagulation Treatment for Landfill Leachate using Stainless Steel Electrode

**Bharath M, B M Krishna**

***Abstract*: Electrocoagulation (EC) process uses direct electric current source between metal electrode submerged in the effluent that results in electrode dissolution, with a suitable pH, metal ion can form a wide range of metal hydroxide and coagulated species that destabilized and dissolved contaminants absorbed. Electrocoagulation (EC) has been working for the percentage removal of BOD (Biochemical oxygen demand)/ chemical oxygen demand (COD) ratio, Color and COD on leachate in a batch Electrocoagulation reactor using stainless steel (SS) electrode. EC technology depends on so many factors such as electrode material, initial pH, applied voltage, inter-electrode distance, and electrolysis time. From the experimental work, results reveal that the maximum percentage of removal achieved were COD and Color 73.5% and 65.0% respectively and increasing BOD/COD ratio 0.11 to 0.62. The optimum inter-electrode distance 1cm with electrode surface area 35 cm2 and optimum electrolysis time of 120 min at optimum applied voltage 12V, stirring speed 250 rpm and pH 9.8. These results proved that the EC process is an appropriate and proficient approach for treating the landfill leachate.***

***Keywords: Landfill leachate; Electrocoagulation; Stainless Steel electrode and Process parameters.***

## I. INTRODUCTION

Leachate can be defined as the rainwater percolation through waste which generates effluent. Leachate may contain high dissolved solids, a large amount of organic matter, suspended solids, chlorinated organic/inorganic salts, ammonia-nitrogen, and heavy metals. The elimination of organic material, such as ammonium, BOD, color, and COD from leachate. There are so many factors that affect the leachate quality, such as seasonal weather, age, composition, precipitation, and waste type. In general, landfill leachate composition mainly depending on the landfill age. The treatment technology for leachate mainly includes physicochemical–nanofiltration processes [1], flocculation/precipitation [2], sequencing batch reactor (SBR) process [3].

Electrocoagulation (EC) has been involved for treating different types of process wastewater, for example, restaurant wastewater [4], electroplating wastewater [5], Distillery wastewater [6]EC process has been effectively used for the treatment and pollutants removal from industrial wastewater, municipal wastewater, and inorganic ion and heavy metal removed. The main importance of research work is to optimize the process parameters such as electrolysis time, inter-electrode distance, voltage (current density) and biochemical oxygen demand (BOD)/COD ratio, color and COD removal efficiencies. EC technique is an easy operation, simple equipment and produces less amount of sludge with an appropriate anode material, and the coagulants are generated by electrolysis oxidation that leads to the insoluble components and metal hydroxide which is capable of eliminating a huge range of contaminants from wastewater [7]. The mechanism of an EC cell can be defined by the following equations 1 to 4.

At the anode, metal is oxidized into cations:

$$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^{-} \quad (1)$$

$$Fe_{(s)} + 2OH^{-} \rightarrow Fe(OH)_{2_{(S)}} \quad (2)$$

At the cathode, water is reduced into hydrogen gas and hydroxyl anions:

$$2H_2O + 2e^{-} \rightarrow H_{2(g)} + 2OH^{-}{}_{(aq)} \quad (3)$$

In the bulk solution

$$Fe^{2+}_{(s)} + 2OH^{-}_{(aq)} \rightarrow Fe(OH)_{2_{(s)}} + H_{2_{(g)}} \quad (4)$$

The objective of this research work is to remove the COD and Color from landfill leachate samples and to understand the effect of various operating parameters such as electrode material, initial pH, applied voltage (current density), electrolysis time and inter-electrode distance using EC process.

## II. EXPERIMENTATION

### A. Study Area for the Treatment of Landfill Leachate:

The area of study was selected for the study is in Mysuru city, Karnataka. It is located at 12.30°N 76.65°E with an average altitude of 770 meters. The dumpsite was situated at Vidyaranyapuram, Mysuru, Karnataka. The dumping of waste in this area is being used from past 6- 7 years. The area consists of accumulated waste of about 2,50,000 cum and the area used for dumping of waste is about 41.47 acres.

The present study attempts to treat landfill leachate using Electrocoagulation process. The sample landfill leachate was collected in the tank wherein, and the leachate is coming from the pipes which have shown in Fig 1. The various physical and chemical parameters were analyzed in this study. The physical and chemical parameters in the initial characterization of the sample were shown in Table 1.

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**Figure 1 Landfill leachate collection tank**

**Table 1 Initial characterization of the landfill leachate Pa rameters**

| Sl. No. | Parameters | Concentration |
|---|---|---|
| 1 | pH | 8.64 |
| 2 | Conductivity | 36.5 mS/cm |
| 3 | Turbidity | 160NTU |
| 4 | Total solids | 14600(mgL-1) |
| 5 | Total Dissolved Solids | 13552-14240(mgL-1 ) |
| 6 | COD | 13760(mgL-1) |
| 7 | Phosphate | 200.5(mgL-1) |
| 8 | Total suspended solids | 1840(mgL-1) |
| 9 | Nitrates | 90.5(mgL-1) |
| 10 | BOD | 1519(mgL-1) |
| 11 | Chloride | 7053(mgL-1) |
| 12 | BOD/COD | 0.1104 (mgL-1) |
| 13 | Color | 8750 PCU |

## B. EC Reactor Setup for Electrocoagulation

EC experiments were carried out in a plexi-glass laboratory scale. Batch electrochemical reactor (11cm x14cm x 13cm) of 2 L capacity with the working volume of 1.75L at room temperature was used in the setup.

The reactor was kept under the process of continuous agitation using magnetic stirrer with 250 rpm to avoid the formation of concentration gradients. The T shaped electrodes with the material of stainless steel (SS) plates with a size of 5 cm X 7 cm was used as both anode and cathode electrode having 35 cm2 effective surface area. At the bottom of the electrodes, the gap of 2 cm was maintained to facilitate continuous and easy stirring. Before each treatment process, the SS electrodes were cleaned and degreased. The power supply used to run all experimental conditions was DC power. The inter-electrode distance between anode and cathode electrode was varied from 1cm to 4cm, wherein the voltage used in the electrolysis process was 4V. The duration of the electrolytic process was done for 180 mins with a 15mins time interval. At every 15 min, the sample was collected for further process. The collected samples after electrolysis were used to analyze the process parameters such as current density, electrolysis duration, Color, COD, BOD/COD ratio, and pH. Among these analyzed parameters, pH, Electrolysis duration, the distance between electrode and voltage (current density) were optimized in this study. The experimental setup for electrocoagulation to the lab scale process has shown in Fig 2. The analytical details as shown in Table 2.


**Figure 2 Experimental set up of electrocoagulation treat ment in a lab-scale**

**Table** 2 **Analytical** details

| Parameters | Analytical technique/Method | Instruments/Equipment's Used, Make |
|---|---|---|
| pH | Digital pH meter | ------- |
| Chlorides | Argentometric method | Standard method |
| Nitrate | Phenoloic disulphonic Acid Method | UV spectrophotometer |
| COD | COD digester (Open reflux system)/Titrimetric | Hach 389, USA |
| Solids | Gravimetry | Hot air oven |
| Phosphate | Ammonium Vandate/Molybdate | UV Spectrophotometer |
| BOD | 27o C, 3 days incubation/ Titrimetric/ Modified Winkler's method | |
| Conductivity | Conductivity meter | ----- |
| Color | Platinum cobalt method | ------ |
| Sulphate | Spectrophotometric method | UV spectrophotometer |
| DC Power Supply Unit | 0-10 A, 0-15 V, DC power supply unit | APLAB, Regulated dual DC power supply LD3210. |

## III. RESULT AND DISCUSSION

The several factors that regulate the process of electrolysis in the removal of biological and chemical contaminations in the wastewater technique include electrode material, the distance between the two electrodes, duration of the electrolysis process, applied voltage (current densities), pH and the presence of other coagulants in the technique. The initial study was done to figure out the removal efficiency of landfill leachate treatment. The detailed study was conducted for the changes in voltage and distance between the electrodes.

### A. Effect of inter-electrode distance on landfill leachate treatment by EC:

The effect of inter-electrode distance has been considered as a process parameter to reduce current consumption for the landfill leachate treatment. The distance of the electrode varied at 1, 2, 3, and 4cm. The COD and Color removal have been observed to increase with decrease in inter-electrode distance from 4 to 1cm. Percentage COD removal and Color removal as shown in Fig 3 and Fig 4.

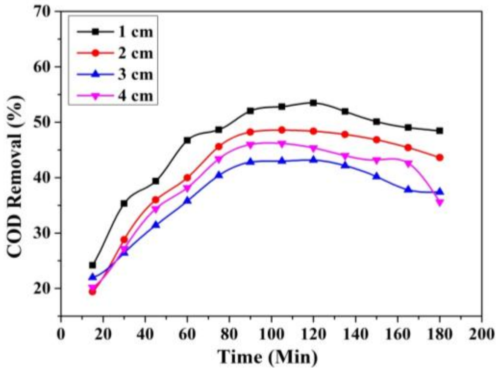


**Figure 3 Percentage removal of COD with different dista nce**

The maximum percentage removal achieved was COD and Color 53.0% and 35.3% respectively, at the shortest distance 1 cm between the electrodes with surface area 35 cm2. Because less than the 1cm spacing between electrodes prevent the flow of liquid adsorbate in the interstitial spaces of the electrodes thus, hindering percentage removal efficiency. Similar observations have been reported by [8]. At the anode, the faster anion discharge takes place, that results in increasing removal efficiency and enhance oxidation, it also minimizes the electrical current consumption, resistance, and price of the leachate wastewater treatment[9].

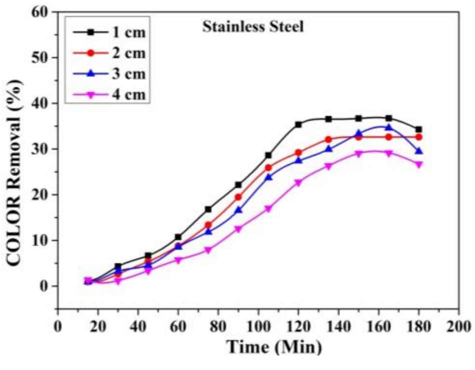


**Figure 4 Percentage removal of Color with different dista nce**

### B. Effect of applied voltage on COD and color removal efficiency:

The applied voltage is a significant parameter that affects the treatment efficiency of the electrocoagulation degradation method. The batch study was carried out to find the effect of voltage on COD and color removal efficiency from leachate. EC experiments have been carried out at 4V, 6V, 8V, 10V, and 12V, as shown in Fig 5 and Fig 6. At 12V maximum COD and Color, removal had been found. It can be noticed that the percentage removal efficiency of COD and Color was relatively high whereas the voltage of 12V. If the voltage (current density) increases, charge loading also increases that leads to increase the pollutants removal [4].

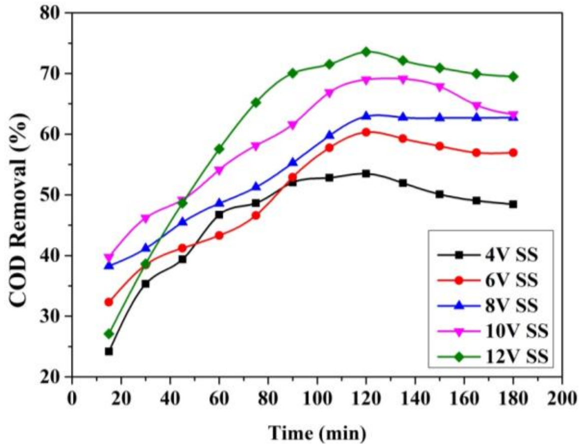


**Figure 5 Percentage removal of COD with different volta ge**

At this voltage, over 73.5 % of COD and 65.0 % of Color was removed. Stainless steel electrodes can be successfully used as anode and cathodes, which make the process more efficient and easier to maintain. The sharp decrease of COD was because of the combined effects of destabilization of colloidal organic compounds and cathodic reduction. Certainly, after EC, a thin brownish deposit layer was noticed on the cathodic electrode surface, that results in the cathodic reduction phenomenon [10]. The voltage of 12V and 120 min was selected as the optimum conditions for the EC treatment.

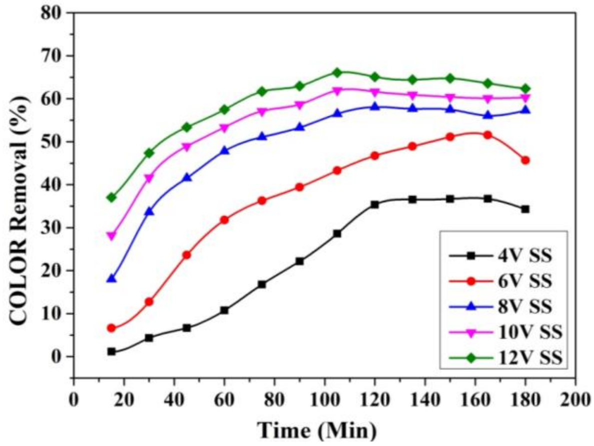


**Figure 6 Percentage removal of Color with different volt age**

### C. Effect of pH changes during electrochemical treatment

In electrocoagulation, it has been proven that pH has a significant effect on COD and Color reduction. The initial pH of the landfill leachate was 8.64 after the end of 120 min electrocoagulation; it was noticed that the pH had been increased to 9.8 at 12 V, as shown in Fig 7. The results reveal that the highest COD and Color removal was 73.5 % and 65.0 % respectively at pH 9.8. Some of the researchers found that pH was the most important controlling operating parameter in electro-oxidation of landfill leachate correlate with chlorine concentration, applied voltage, temperature, and leachate input rate. Because of dominant activities at the cathode pH increases gradually [11]. In neutral and alkaline condition, decolorization of effluent is very high but very less in acidic condition. At the cathode, the production of hydroxide results in electrochemical reduction. pH variation did not significantly change COD removal in electro-oxidation of leachate. [12].

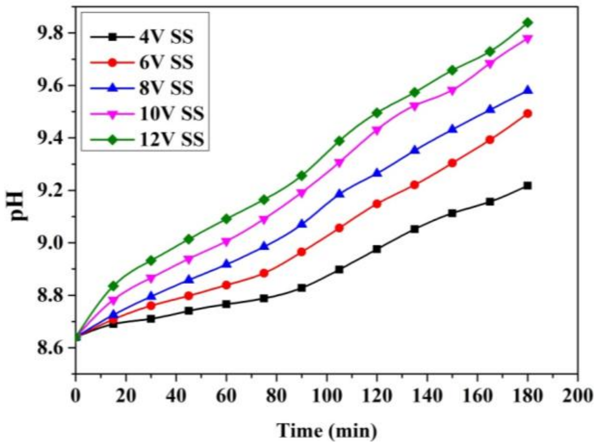


**Figure 7 Effect of pH versus electrolysis time**

### D. Effect of BOD/COD ratio changes during the EC process

From Fig 8, it is observed that there was an improvement in biodegradability of landfill leachate evaluated through the evolution of the BOD/COD ratio. With a raise in BOD/COD ratio from 0.11 to 0.62 at optimum time 120 min, voltage 12, and distance 1 cm. It can be observed that when the voltage increases the degradation of COD also increases consecutively, the BOD/COD ratio of the effluent also increases.

This is due to increasing voltage, increase the overall potential essential for the production of chlorine and hypochlorite. Under different voltage, the other operating condition was altered, and the performance of the reactor also affected. An increasing BOD/COD ratio signifies a remarkable improvement of biodegradability [13]. The low BOD/COD ratio (0.11) in the effluent specifies that it contains recalcitrant substances which were not easily biodegradable or non biodegrabale material present in leachate [14].

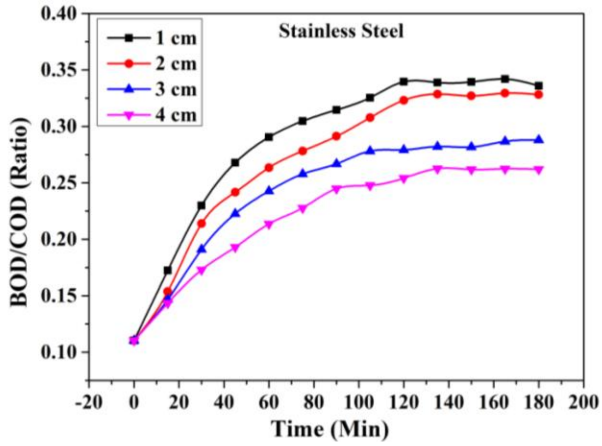


**Figure 8 Effect of BOD/COD ratio vs Electrolysis duration**

## IV. CONCLUSIONS

Electrocoagulation technique is a promising process for the remediation and degradation of effluents of low bio-degradability. The research work shows that the performance of electrocoagulation is an efficient process for treating landfill leachate. Stainless steel electrodes were used for performing electrocoagulation. To optimize the process parameters such as inter-electrode distance, applied voltage, electrolysis time, and effect of initial pH. From that experimental work, some of the conclusions are drawn.

- The maximum removal achieved was COD and Color, 53.0 % and 35.3% respectively, at the shortest inter-electrode distance of 1cm.
- The result reveals that an increase in BOD/COD ratio from 0.11 to 0.62.
- The higher removal efficiency was obtained COD and Color, 73.5% and 65.0% respectively, at the optimum electrolysis time of 120 min. Optimum inter-electrode distance 1cm at optimum applied voltage 12V, pH 9.8, and stirring speed 250 rpm.
- The results reveal that EC is more efficient for removal of COD, Color, and BOD/COD ratio in leachate.

## REFERENCES

1. D. Trebouet, J. P. Schlumpf, P. Jaouen, and F. Quemeneur, “Stabilized Landfill Leachate Treatment By Combined Physicochemical – Nanofiltration Processes,” vol. 35, no. 12, pp. 2935–2942, 2001.
2. A. Amokrane, C. Comel, and J. Veron, “Landfill leachates pretreatment by coagulation-flocculation,” Water Res., vol. 31, no. 11, pp. 2775–2782, 1997.
3. S. Q. Aziz, H. A. Aziz, M. S. Yusoff, and M. J. K. Bashir, “Landfill leachate treatment using powdered activated carbon augmented sequencing batch reactor (SBR) process: Optimization by response surface methodology,” J. Hazard. Mater., vol. 189, no. 1–2, pp. 404–413, 2011.
4. X. Chen, G. Chen, and P. L. Yue, “Separation of pollutants from restaurant wastewater by electrocoagulation,” Sep. Purif. Technol., vol. 19, no. 1–2, pp. 65–76, 2000.
5. K. Dermentzis, A. Christoforidis, E. Valsamidou, A. Lazaridou, and N. Kokkinos, “Removal of Hexavalent Chromium From Electroplating Wastewater By Electrocoagulation With Iron Electrodes,” Glob. NEST J., vol. 13, no. 4, pp. 412–418, 2011.

6. B. M. Krishna, U. N. Murthy, B. Manoj Kumar, and K. S. Lokesh, "Electrochemical pretreatment of distillery wastewater using aluminum electrode," J. Appl. Electrochem., vol. 40, no. 3, pp. 663–673, 2010.
7. N. Adhoum and L. Monser, "Decolourization and removal of phenolic compounds from olive mill wastewater by electrocoagulation," Chem. Eng. Process. Process Intensif., vol. 43, no. 10, pp. 1281–1287, 2004.
8. D. Ghosh, C. R. Medhi, H. Solanki, and M. K. Purkait, "Decolorization of Crystal Violet Solution by Electrocoagulation," vol. 2, pp. 25–35, 2008.
9. M. O. Orkun, "Treatment Performance Evaluation of Chemical Oxygen Demand from Landfill Leachate by Electro-Coagulation and Electro-Fenton Technique," vol. 31, no. 1, pp. 59–67, 2012.
10. 10.M. Asselin, P. Drogui, H. Benmoussa, and J. Blais,"Chemosphere Effectiveness of electrocoagulation process in removing organic compounds from slaughterhouse wastewater using monopolar and bipolar electrolytic cells," vol. 72, pp. 1727–1733, 2008.
11. 11.F. Ilhan, U. Kurt, O. Apaydin, and M. T. Gonullu, "Treatment of leachate by electrocoagulation using aluminum and iron electrodes," J. Hazard. Mater., 2008.
12. 12. Y. Deng and J. D. Englehardt, "Electrochemical oxidation for landfill leachate treatment," Waste Manag., vol. 27, no. 3, pp. 380–388, 2007.
13. 13. J. L. De Morais and P. P. Zamora, "Use of advanced oxidation processes to improve the biodegradability of mature landfill leachates," J. Hazard. Mater., vol. 123, no. 1–3, pp. 181–186, 2005.
14. 14. C. Visvanathan, M. K. Choudhary, M. T. Montalbo, and V. Jegatheesan, "Landfill leachate treatment using thermophilic membrane bioreactor," Desalination, vol. 204, no. 1–3 SPEC. ISS., pp. 8–16, 2007.

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