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Municipal Wastewater Treatment By Electrocoagulation

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ABSTRACT: This paper aims at the suitability of Electrocoagulation for the treatment of municipal wastewater. The process was evaluated with a laboratory scale model with Aluminum anode and stainless steel cathode due to its high efficiency in the removal of apparent color and organic matter. The experiment was conducted with municipal wastewater. The initial and final characterization of wastewater is done for various parameters and the Electrocoagulation is evaluated for the highest efficiency. The optimal condition COD removed found to be was 80.70% and Total Solids was 61.38% at 25 minutes of electrolysis time, 10V applied potential and 2cm inter electrode distance. Also the floating and settling behavior of the sludge is studied.

Keywords : Electro-coagulation, Wastewater Treatment, Aluminium electrodes, COD, Total Solids

1 INTRODUCTION

Untreated municipal wastewater results in harmful effects for human and aquatic life. Moreover it contaminates land and water bodies. Eutrification is one of the main problems [1]. Rapid growth in population puts in more and more pollutants in to the surrounding environment. Activated sludge process, Upflow anaerobic sludge blanket, Oxidation pond and trickling filters are the main treatment methods adopted for the treatment of municipal wastewater [2]. Sensitivity of biological processes and high volume secondary sludge production made advance treatment methods more acceptable. And elctrocoagulation is one of the widely used advanced methods used to treat wastewater. Electrocoagulation was widely accepted at the end of the 19th century in Europe and America. Electrocoagulation has been successfully used for the treatment of wastewater such as electroplating industry[4],chemical mechanical polishing industry[5], laundry industry[6],pulp paper mill industry[7], Textile industry[8], water purification[9,water defluoridation and industrial water defluoridation[10], olive oil mill industry[11], tannery industry[12], baker's yeast industry [13]and slaughterhouse [14]. Current study elaborates aptness of Elelctrocoagulation technique with aluminium and stainless steel electrodes for the treatment of municipal wastewater within effective time. It includes the characterization of influent and effluent water. By calculating COD and TS the efficiency of the system is determined by varying time, inter electrode distance and applied potential.

2 MECHANISM

When direct current is applied between electrodes, sacrificial anode is dissolved into the electrolyte. The dissolved ions help in the removal of colloidal particles from the solution by destabilization and flotation [15]. The reactions occurred at various electrodes are described below.

Anodic reactions:
$Al\ (s) \rightarrow Al^{3+}\ (aq) + 3e^-$

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

Solution reactions:
$Al^{3+}\ (aq) + 3OH^-\ (aq) \rightarrow Al(OH)_3(s)$[16].

It also results in the formation of large number of monomeric and polymeric species like $Al(OH)^{2+}$, $Al(OH)_2^{+}$, $Al_2(OH)_2^{4+}$, $Al(OH)_4^{-}$, $Al_6(OH)_{15}^{3+}$, $Al_7(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$, $Al_{13}O_4(OH)_{24}^{7+}$, $Al_{13}(OH)_{34}^{5+}$[17].

3 MATERIALS AND METHODS

3.1 WASTEWATER

The wastewater is collected from sump at- “Hindustan University STP Plant” Chennai. For each run 500ml sample is taken and vigorously mixed to provide homogeneity of the solution. The Initial characteristics of the wastewater are determined and presented in table 1. The analysis of municipal wastewater is by titrimetric and gravimetric methods using the instruments described as follows. pH of the sample was measured using HANNA, H1 207 pH meter. The COD of wastewater was measured by closed Reflux method. The measurement of conductivity was done using La-Motte Conductivity Meter and turbidity by Delux-335 nephlometric turbidity meter. Gravimetric methods were used for the determination of the TS and Alkalinity. Chlorides were measured by titrimetric methods, as prescribed in Standard Methods (APHA) for water and wastewater analysis.

TABLE 1
INITIAL CHARACTERISTICS OF THE SEWAGE

S. No.	Parameter	Value
1	Chemical Oxygen Demand (mg/l)	332
2	Turbidity (NTU)	297
3	Conductivity (µs)	1280
4	Total solids (mg/l)	984
5	Chlorides (mg/l)	280
6	ph	7.08

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3.2 REACTOR

The reactor was fabricated using acrylic sheet with an internal dimensions 12.5 × 8 × 9 (L×B×H) cm, having a volume of 900ml. In the reactor aluminum electrode is used as the anode due to its high efficiency in the removal of organic matter and stainless steel electrode is used as the cathode as it is highly efficient in the production of small bubbles and also it is electrochemically non reactive. The wetted surface area of the electrodes is 90cm2. 90 minutes of settling time was allowed after each run. Magnetic stirrer was used for the proper mixing, besides it can alter the floating and settling characteristics of the sludge. 1 minute of rapid mixing and 4 minutes of slow mixing is done after each run for getting completely settled sludge. The schematic diagram of electro-chemical reactor is shown in Fig 1.

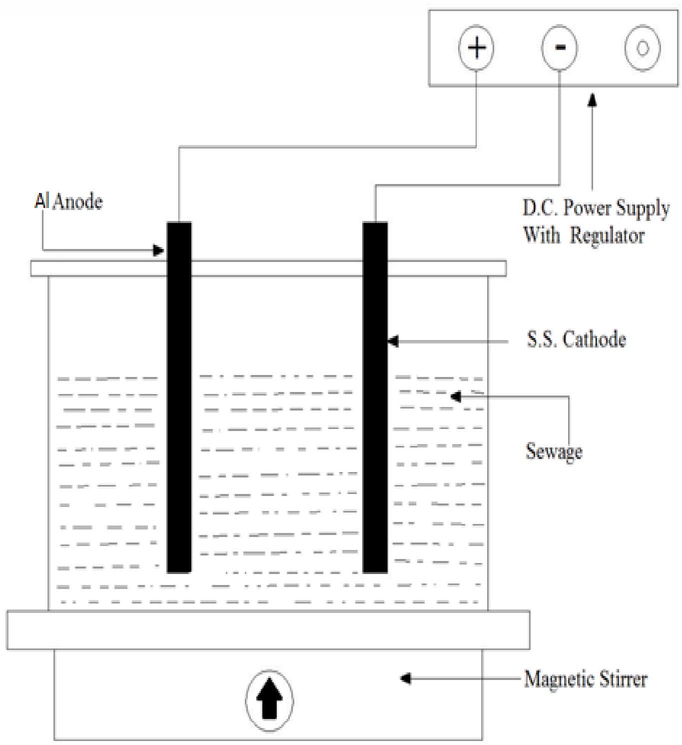

***Fig 1:** Schematic diagram of electro coagulation unit*

3.2.1 EFFECT OF THE INTER ELECTRODE DISTANCE IN WASTEWATER TREATMENT

The distance between the electrodes is varied from 1 to 4cm and the experiment is conducted. The electrolysis time was kept as 20 minutes. Table 2.1 gives the performance of electro-coagulation unit with respect to different electrode distance. The optimum distance obtained was found to be 2 cm for both COD and TS. The obtained values of COD and TS with respect to different inter electrode distances are discussed in figure 2(graph). At an inter electrode distance of 1cm at 12 V the efficiency was low compared to a distance of 2cm at 12V. The reason behind this phenomenon is, at lesser inter electrode distance more aluminium ions are liberated into the solution than required. It results in more dissolved aluminium in the medium. When the distances between the electrodes were increased more than 2cm, the efficiency of the system decreases due to the insufficient metal ions for proper coagulation of colloidal particles present in the wastewater.

TABLE 3.2.1
COD & TS VALUES WITH CHANGE IN INTER ELECTRODE DISTANCE

Electrode distance (cm)	COD (mg/l)	TS (mg/l)
1	192	453
2	160	402
3	192	464
4	224	480

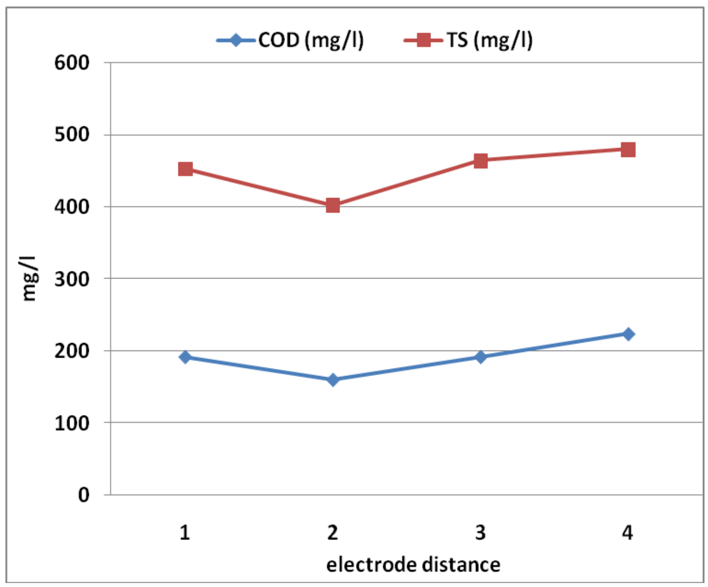

***Fig 2:** Electrode Distance v/s COD and TS*

3.2.2 EFFECT OF ELECTROLYSIS TIME ON WASTEWATER TREATMENT

The removal efficiency of COD and TS with respect to electrolysis time with a constant applied voltage is determined .To determine this, an optimal inter electrode distance of 2 cm is considered .the electrolysis time is varied from 10 minutes to 30 minutes. The maximum efficiency is obtained at 25 minutes for both COD and TS. The values of COD and TS are tabulated in table number 2.2. Figure 3 explains how COD and TS values reduce and increase with varying electrolysis time. From the above table it is understood that the treatment efficiency of COD and TS increases with time. The efficiency gets reduced after 25 minutes. After the optimal point more and more metal ions from anode are contributed to the solution. These free ions further result in an increased pollutant level in solution.

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TABLE 3.2.2
COD & TS VALUES WITH CHANGE IN ELECTROLYSIS TIME

Time (min)	COD (mg/l)	TS (mg/l)
10	224	524
15	192	434
20	128	404
25	96	396
30	128	456

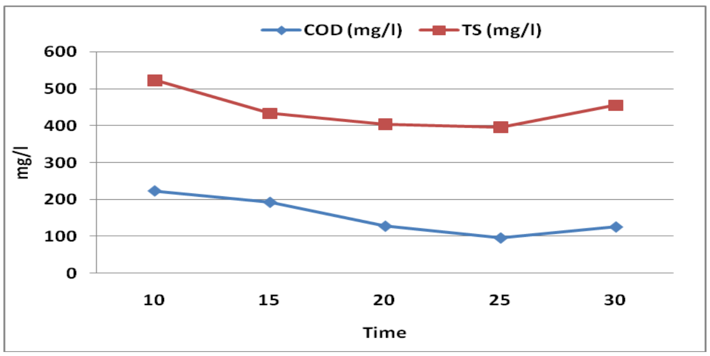

Fig 3: *Time v/s COD and TS*

3.2.3 EFFECT OF APPLIED POTENTIAL ON WASTEWATER TREATMENT

Applied Potential is one of the important parameters that should be considered while determining the COD and TS removal efficiencies. In this experiment the Applied Potential is varied from 8v to 16v using a regulator. The electro coagulation experiment is carried out with 2 cm inter electrode distance and 25 minutes of electrolysis time. As the applied voltage increases more aluminium ions get dissolve in to the solution. If more aluminium ions get dissolved into the solution the efficiency of the process get reduced. Figure 4 shows the relationship of above mentioned values.

TABLE 3.2.3
COD & TS VALUES WITH RESPECT TO VARYING APPLIED VOLTAGE

Voltage(v)	COD (mg/l)	TS (mg/l)
8	96	422
10	64	380
12	96	434
14	128	456
16	160	494

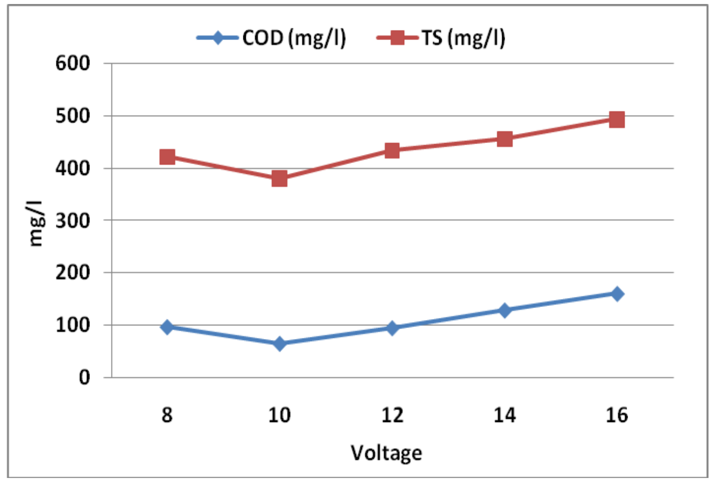

Fig 4: *Volt v/s COD and TS*

4 RESULTS AND DISCUSSION

4.1 OPTIMIZATION OF THE PROCESS

Optimization of the electrocoagulation system is done based on different applied voltage, Time, and Inter-electrode distances. By conducting series of electro coagulation experi ments, it is concluded that the most favorable conditions are at 10V and 2cm inter-electrode distance, with 25 minutes electrolysis time. Figure 5 shows the full set up of electrocoagulation unit.

Fig 5: *ELECTROCOAGULATION UNIT*

Final characterization of the treated water was done in the optimal condition and the values are given in table 4.1.The efficiency for the removal of the various parameters is also determined. It is found that the values are within the limits of the CPCB norms

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TABLE 4.1
FINAL CHARACTERISATION OF WASTEWATER

S. No.	Parameter	Effluent	%of removal
1	Chemical Oxygen Demand (mg/l)	64	80.70
2	Turbidity (NTU)	46	84.50
3	Conductivity (µs)	562	56.09
4	Total solids (mg/l)	380	61.38
7	Chlorides (mg/l)	220	21.43
8	pH	7.32	-

5 CONCLUSION

In the present study it is found that the most favorable condition for the wastewater treatment is at an applied potential of 10 v with 2cm inter electrode distance and with an electrolysis time of 25 minutes. At this optimal setting the COD got reduced from 332 mg/l to 64mg/l and TS got reduced from 984mg/l to 380mg/l, Therefore the COD removal is 80.70% and TS removal is 61.38%. During this Electrocoagulation the pH and alkalinity are likely to increase due to the formation of hydroxide ions in the solution. The sample considered in the study behaved in such a way that the pH change was within the limits. The increase in applied voltage and electrolysis time improved the efficiency of the time. Lesser inter electrode distance produce more anions which increase the efficiency of the treatment level. Thus the optimal level of the parameter setting is determined and the sample is treated at this optimal setting and the treatment efficiency found out.

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