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Wastewater Treatment by Electrocoagulation Process: A Review

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Abstract: Electrocoagulation is the process of removing suspended, dissolved, heavy metals, organic and emulsified pollutants by applying direct current to electrodes for dissolution. The electrocoagulation process is widely used in various industrial water treatment plants due to its low cost material and process design. In this frame, the paper presents a general review of EC technologies employed for various samples of wastewater like dye mixed synthetic wastewater, sewer wastewater, and dairy wastewater using different power supply models of EC having PV model and DC power supply.
Keywords: Electrocoagulation, Wastewater, Photovoltaic energy, Municipal waste, BOD

I. INTRODUCTION

The technologies available for wastewater treatment have been applied for a long period of time. Most of these technologies in water treatment are consuming a huge amount of energy. Treatment technologies for wastewater can be classified as a physical treatment technology that includes screening, floatation, filtration, sedimentation in three groups. Technology for chemical treatment contains techniques of coagulation, flocculation, chlorination, adsorption, and ion exchange. And the last is biological treatment cycle including filter trickling, aerated lagoons, activated sludge, biological contactors rotating [4]. Electrocoagulation was first filed to treat sewage in England at 1889, and used for wastewater treatment in USA at 1946. However, the application of electrocoagulation was restricted due to high power cost and large capital investments [8]. Since, the rapid development in power industry and the increasing complexity of wastewater, the interest in the application of electrocoagulation has been renewed.

Electrocoagulation is employed with sets of electrodes connected parallel or in series with power source. This process does not require any other chemical for treatment. The electrodes used in this process are either made of Iron or Aluminum. The advantage of using Aluminum as electrodes is that it firstly increases the pH if the pH of water is initially acidic and decrease pH when the initial pH is alkaline. Thus, electrocoagulation using aluminum electrode acts as pH neutralizer. Electrocoagulation treatment eliminates further pH adjustment of effluent [3].

II. LITERATURE REVIEW

Edris Bazrafshan et al. conducted a study on Dairy wastewater. The wastewater was poured into electrocoagulation cell after 12 hours of traditional settling. The Bipolar batch reactor with 6 aluminum electrode connected in parallel was used for all the experiment. The maximum removal efficiency is achieved by applying voltage of 60V. However, the minimum removal efficiency is obtained at low voltage of 10V. Thus, the study shows the applicability of electrocoagulation in treatment of wastewater of dairy industry. The highest voltage reduces the COD, BOD_5, and Bacterial concentrations [5].

Billal Khemila et al. in their experiment used a PV model as an energy source for electrocoagulation. The actual dye of textile industry is used to prepare the synthetic wastewater. NaCl, HCl and NaOH were used to fix the conductivity and the pH of the wastewater. The Reactor of 8.5L capacity including sedimentation and chemical settling was used. Fractions of the total liquid were taken from electrocoagulation tank at regular time period. The estimation of the dye concentration is carried out by using UV-visible spectrophotometer. On comparing the concentration of inlet and outlet of the dye with the amount of the energy per kg of dye and per m^3 of wastewater is given as results [1].

C.J. Nawarkar et al. conducted an experiment on the municipal wastewater. The sample was first settled in a settling tank then used in an electrocoagulation cell of acrylic glass of volume 1.66L. The cell consisted of the 6 Aluminum electrode plates as 3 Anode and 3 Cathode arranged alternatively (parallel arrangement). The electrocoagulation cell is provided with predetermined flow rates to get various detention times and the current density accordingly. The sample is drawn in a beaker after EC process for 30 min later used to determine the turbidity, COD and TDS and came to conclusion that the solar powered electrocoagulation used is cost effective and more efficient than chemical coagulation [2].

III. MECHANISM

Electrocoagulation obeys the Faraday's Law which states that, (m= AWIt/zF) [10] where m is total mass of electrode (Aluminum), AW is the atomic weight of the electrode material. I is electric current, t is time, z is number of electron transferred and F is Faraday's constant. Electrocoagulation is the process where the suspended, dissolved and emulsified pollutants are destabilized in aqueous medium by supplying power in the form of electricity [8]. In electrocoagulation process, coagulants produced by in situ by electrodissolution of sacrificial anode. The chemical reactions at electrodes can be written as:

At Anode:

$$M \rightarrow M^{n+} + ne^{+}$$

Here, n is the number of electron transferred by dissolution process at anode.

At Cathode:

$$3H_2O\ 3e^{-} \rightarrow 3/2\ H2O + 3OH^{-}$$

Thus, the amount of Aluminum dissolved by anionic oxidation can be calculated by Faraday's Law, which means that the mass of Aluminum is a function of the electric current and the time of electrolysis [6]. To reduce electrode passivation at anode, the electrodes were clean with the dilute HCl (5% v/v) solution after each batch of experiment and wash again with tap water and finally weighted to calculate the sacrificial electrode consumption [5].

IV. METHODS

A. EC for Dairy wastewater

The water used in the milk processing plant after being used have high TDS and TSS. For each batch, the water was initially settled in a settling tank for 12 hours and then poured into electrocoagulation tank. The Bipolar batch reactor with 6 aluminum electrode connected in parallel was used for all the experiment. The outer electrodes were only connected to power supply. The internal dimension of the cell was 15*15*25 cm^3 with the effective volume of 2000m^3 and the feed volume of each batch was 2L. The total submerged areas of electrodes were 280 cm^2 and the 2 cm gap between two electrodes. The variable voltage of 0-60V and maximum current of 5A is provided by DC source. The system temperature is maintained at 25±2°C. The samples of 100-150 mL were filtered to determined BOD_5, COD, TSS, and other parameters for each sample taken after 15 min intervals up to 1 hour. The standard methods were used to determine the COD, BOD_5, TSS, pH, conductivity, and coliforms. For the first 12 hours of preliminary settling, the COD was removed by 22%+, BOD_5 was removed by 16-17%, TSS was reduced more than 57%. The supply of more voltage leads to form more Al^{3+} ions which results to increase the solubility of ions and increase in formation rate of $Al(OH)_3$. Thus, the removal efficiency at 7.24 pH of wastewater was more than 97% after 1 hour of electrocoagulation for all voltage from 10V to 60V. On considering the results, the COD removal efficiency at 10V was approximately 60.6%. For the same effluent the COD removal efficiency at 60V was found 98.8%. Thus, the pollutant concentration in the wastewater significantly decreased on increasing in voltage from 10V to 60V.

TABLE I
Influence of Electrocoagulation process using aluminum electrodes [5].

Applied Voltage [V]	COD [mg/L]	BOD_5 [mg/L]	TSS[mg/L]
10	2405.96	892.2	372.43
20	1390.99	484.47	298.18
30	1143.98	432.55	167.89
40	681.74	379.35	131.76
50	649.94	310.27	26.73
60	70.92	43.45	16.52

B. Photovoltaic Electrocoagulation

A photovoltaic module, by application of photoelectric effect, converts the sunlight into DC electricity. In this method, the power supply for electrocoagulation was PV module. The synthetic wastewater sample for this method was made by adding the actual dye from textile industry in tap water. The concentration of the synthetic waste water was 50-1400 mg L^{-1}. Suitable amount of NaCl was added to get the conductivity of 2.5 mS cm. The pH value was adjusted by adding dilute solution of HCl or NaOH. The concentration and the conductivity were set according to the properties of the wastewater of the textile industries.

The Photovoltaic electrocoagulation cell consists of 8.5 L of tank having sedimentation/floatation chamber of 5.5 L and the electrochemical tank of 3 L. Two aluminum electrodes of 24*2*1 cm^3 were positioned vertical to tank and the parallel to each other having 1 cm of gap between each other. The area of each side of electrodes was 48 cm^2. 40 mL of sample were taken from the electrochemical tank at regular period of time. Dye concentration was estimated by using UV-Visible range from its absorbance characteristics (The dye has the maximum UV absorption of 502nm). Various data like, wavelength, conductivity, pH, turbidity of wastewater.

TABLE II
Effect of Input Flow Rate on the Turbidity and Absorbance Elimination Rate [1].

τ [minutes]	Q [L/h]	Absorbance [%]	Turbidity [%]
35	15	92	93.5
19	26	91.5	94.4
14	38	88.7	96.5
9	60	83	95

C. Municipal Wastewater Treatment using Electrocoagulation

The sample wastewater collected from the sewer by grab sampling method. The collected sample was stored in settling tank. The settled wastewater was used in electrocoagulation. The electrocoagulation was carried out in a tank of dimension of 120*150*92 mm^3 made of acrylic glass having capacity of 1.66 L.

The cell consisted of the 6 Aluminum electrode plates as 3 Anode and 3 Cathode arranged alternatively (parallel arrangement) having 1 cm gap between each electrodes.

The electrodes are placed alternatively at top and the bottom as the baffles in heat exchangers to provide up flow and down flow of wastewater. The effective area of electrodes was 0.0210 m^2 and effective volume of 1 L. The solar photovoltaic module was used as the power source consisting 2 PV panels each having capacity of 60 W. The electrocoagulation experiment was carried out on samples continuously.

Each sample with calculated flow rate fed to the electrocoagulation tank for retention time of 4 min to 24 min and accordingly the current density varies between 8 A/m^2 to 64 A/m^2. The wastewater leaving the electrocoagulation tank was taken as sample in a glass beaker and given 30 min time to settle down. That sample was later tested for determination for COD, TDS, conductivity, pH and turbidity. The results found that the removal efficiency at current density of 48 A/m^2 and hydraulic detention time of 16 min are 90% for COD, 94.56% for Turbidity and 49.78% for TDS.

V. APPLICATIONS

Electrocoagulation is effectively applicable for various water and effluent treatment mainly in 6 industries as [7] Water having heavy metal is discharged from various industries. The heavy metals are non-biodegradable and some of them are toxic. Therefore, it is essential to remove heavy metals from wastewater discharge. Textile industry wastewater is highly contaminated with organic materials and different types of dyes. Also, chromium is found in the wastewater of textile industries which is carcinogenic. Food Industry wastewater has high contamination biodegradable non toxic materials of high BOD, COD, TSS and TDS. The blackish effluent in paper industry has high contamination of lignin, BOD, COD, TSS, organic material and arsenic. The wastewater from refinery or petrochemical industry has high contamination of aromatic, aliphatic hydrocarbons, chemicals, TDS, COD and BOD. Oil and gas industry produces large amount of water. The composition of the water depends on the product and the method of extraction employed.

VI. CONCLUSION

Electrocoagulation experiments were carried out to find the effect of the detention time, current density, applied voltage to the removal efficiency of COD, BOD_5, TDS, TSS, pH, Conductivity, turbidity or other parameters of the wastewater. There is no chance of secondary pollution due to high concentration of chemicals as it does not need to add any extra chemicals for coagulation. The Electrocoagulation process is more efficient than the chemical coagulation and does not require additional pH adjustment step. The process can be effectively carried out with DC source. However, the photovoltaic model is more economic for electrocoagulation.

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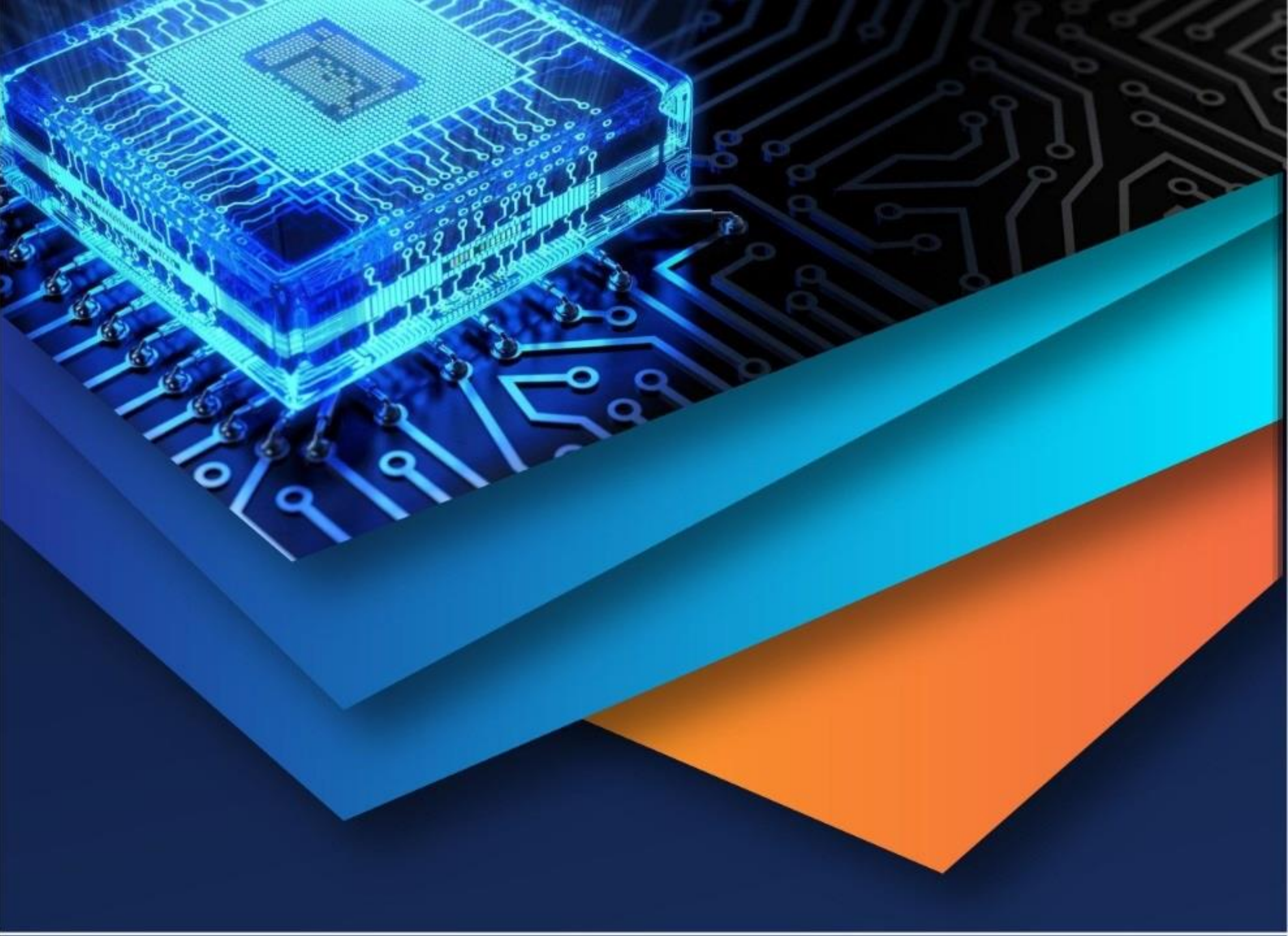

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