TREATMENT OF HOSPITAL EFFLUENT BY ELECTROCOAGULATION

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***Abstract*— Electrocoagulation of hospital effluent was studied using an electrode combination in batch mode of operation. The effluent was characterized and the removal efficiency was determined by the reduction in chemical oxygen demand (COD) of the effluent. The effect of operational parameters such as distance between the electrodes, current density, and agitation speed and electrolysis time on the COD removal efficiency was investigated. The Fe-Fe electrode combination resulted in high COD removal efficiency compared to Al- Al and Fe-Al electrode combination.**

Keywords -Hospital effluent; Iron; Chemical oxygen demand.

I. INTRODUCTION

A variety of wastewater treatment techniques including physical or physicochemical, chemical and conventional biological process are available for the treatment of effluent. The commonly used physico-chemical treatment process is chemical coagulation in which a coagulant is added to the wastewater and allows the formation of flocs for the removal of pollutants. The sludge is separated from the clear water using sedimentation. But chemical coagulation leads to generation of large amount of sludge and sludge disposal becomes a problem. Further, chemical coagulation leads to an increase in total dissolved solids. Electrocoagulation (EC) is an attractive technique for the treatment of effluent in which there is an in-situ generation of coagulant by the dissolution of sacrificial anode. The application of current leads to the generation of hydroxide ions at the anode and hydrogen gas at the cathode. The generation of the hydroxide ions leads to the formation of flocs, which settles the pollutant and can be easily removed by sedimentation. There is formation of gas bubbles, which entrains the lighter pollutants and brings to the surface of the effluent where they can be removed by flotation. Aluminum and iron metals have been commonly used as electrodes since they are cheap and easily available. The reactions occurring in an electrochemical cell for an aluminum electrode are as follows:

At the cathode: $3H2O + 3e^{-} \rightarrow 3/2H2\ (g) + 3OH^{-}$ (1)

At the anode: $Al(s) \rightarrow Al+3(aq) + 3e^{-}$ (2) In the solution: $Al+3(aq) + 3H2O \rightarrow Al(OH)3 + 3H+$(3)EC has been applied for the treatment of textile wastewater, distillery effluent, paper mill effluent , metal plating wastewater, egg processing wastewater , refractory oily wastewater and electroplating wastewater but there is no data available on the treatment of operation theatre wastewater using electrocoagulation. The hospital effluent contains toxic and hazardous substances that are discharged into the urban drainage networks without prior treatment. The hospital effluent contains specific substances such as drug residues, chemical reactants, disinfectants, detergents, developers, radiographic fixing agents, etc. which can lead to health and environment problems. The hazardous substances are a major concern with respect to both health and the environment. In the present study, efforts were made to explore the feasibility of using electrocoagulation for the treatment of the hospital operation theatre effluent.

In India major concern with the hospital wastewater is that, it is been discharged into the sewage network without any primary treatment. And the conventional wastewater treatment facility provided for the treatment of collected wastewater is not able to meet the effluent quality standard for the hospital wastewater effluent. Hence, the aim of the present study is:

1. To explore the feasibility of using electrocoagulation for the treatment of hospital wastewater.
2. To determine the optimum operating conditions for the maximum COD removal and minimum electrode material consumption.

Several researchers have studied a domestic wastewater Sarala (2012), reported that wastewater usually consists of a number of contaminants, such as TSS,TDS,COD, and colors. a wastewater sample is tested in experimental work, with EC after passing each current(0.12, 0.25 and 0.36) amp for each time period(5, 10, 15 and 20) minutes .The result of the study was shown that the maximum reduction of COD and TDS at 20 minutes for 0.25 amp. While Saleem et al. (2011), found that the application of 24.7 mA⁄cm2 current density with an inter electrode spacing of 5 cm may provide 91.8%, 77.2% and 68.5% removal in turbidity, COD, and TSS within 30 min of EC treatment. Rodrigo et al.(2010), indicated that is a capability of removing ionic phosphorus and COD, when using conductive-diamond electrochemical oxidation and electrocoagulation for persistent organic consumption, specifically regeneration of urban wastewater. The study stated that energy consumption is capable of removing at values lower than 4.5 kWh/m3.

Industrial Wastewater Treatment

Several literature has been published on wastewater treatment .El-Ashtoukhy et al. (2013) and others have examined the removal of phenolic compounds from oil refinery waste effluent using an electrochemical reactor with a fixed bed anode that has been made of randomly oriented Al. raschig rings packed in a perforated plastic basket located above the horizontal cathode. The phenolic compounds removal,was investigated in terms of various parameters in a batch mode namely: pH, operating time, current density, initial phenol concentration, the addition of NaCl, temperature and the effect of phenol structure (effect of functional groups). The chemical oxygen demand (COD) was measured as well . The study revealed that the optimum conditions for the removal of phenolic compounds were achieved at current density = 8.59 mA/cm2, pH = 7, NaCl concentration = 1 g/L and temperature of 25°C. Remarkable removal of 100% of the phenol compound after 2 hrs can be achieved for 3 mg/L phenol concentration of real refinery wastewater. The new anode design of electrocoagulation cell permits high efficiencies with lower energy consumption in comparison with the other cell design used in previous studies.

Gao et al. (2013) argued that an effective electrochemical approach for simultaneous silver recovery and cyanide removal from electroplating wastewater was presented. Accordingly, pulse current (PC) electrolysis with parameters including voltage (4.0 V), frequency (800 Hz), and duty cycle (50%) were settled using static cylinder electrodes. Then the influences of technological conditions on the electroplating wastewater treatment process has been widely investigated, which manifested that the concentration of silver ions in electroplating wastewater could be reduced from 221 to 0.4 mg L−1 and cyanide could be simultaneously removed from 157 to4.9 mg L−1 after 3.0 h of PC electrolysis at pH 9.5 ± 0.5, aeration rate of 100 L h−1, and stirring speed of 1000 rpm with NaCl addition of 0.05 mol L−1 at room temperature. The results of XRD and EDX analysis showed that the silver deposits on the cathode were crystalline in face centered cubic structure and had a high purity. To determine the effects of the treatment experiment by EC Zongo et al. (2012) traces that the effluents allowed to eliminate chromium and to lower COD up to 86% abatement. The process designed for the treatment of liquid waste from tannery works at 10.5 m3 hr-1 for current density of 67.5 A.m-2, 62.5 V, 1.2 kWh m-3 energy consumption, and produces 86,000 m3 of clear water with 200 mg L-1COD, 0 turbidity, 91% color abatement, 0 ppm chromium. The treatment produces nearly 480 m3 yr-1 of sludge after compression using filter-press and 216 T of dry matter contain chromium and iron hydroxides, organic and inorganic pollutants. Mansouri et al. (2012) highlighted the Electrocoagulation using aluminum electrodes achieved a high removal efficiency of chemical oxygen demand (≥80%) from aqueous solutions containing 0.51 g·L−1 tannic acid. The primary mechanism implicated in eliminating tannic acid from water by electrocoagulation using Al. electrodes involves the adsorption of tannic acid molecules on the aluminium hydroxide surface. The results of the treatment of real wastewater obtained from the pulp and paper industry with an initial chemical oxygen demand (COD) concentration of 1450 mg·L−1 have shown that more than 60% of COD can be removed by electrocoagulation using Al electrodes under optimized experimental conditions. The specific energy required for the electrochemical process with Al electrodes was estimated to range from 1 to 2 kWh·m−3.Ali and Yaakob (2012) preliminary work on on POME samples were collected from Sri Ulu Langat Palm Oil Mill with COD, turbidity and pH around 50,000 mg/L, 2800 NTU and 4 respectively. Water samples were collected from usual tap water in the laboratory, the pH of tap water was 6 to 8.5. The pH of the water was adjusted to pH 4 by using 1N HCl. The production of hydrogen gas from POME during electrocoagulation was also compared with hydrogen gas production from tap water at pH 4 and tap water without pH adjustment under the same conditions to highlight the advantageous aspects hydrogen production and wastewater treatment simultaneously. Produce hydrogen gas while treating POME with EC to reduce COD and turbidity effectiveness is the main advantage of this study. Electrocoagulation was performed at different voltage (2, 3 and 4 volts). A reactor containing volume 20 liters of POME or water was used to conduct EC experiments. The maximum hydrogen gas produced was about 22.68 liters/hour and an efficient reduction of COD and turbidity of POME by as much as 57% and 62% was achieved respectively. The way in which the chromate removing strain that isolated from spent chrome effluent and identified as Bacillus circulans strain MN1 was studied extensively by Chaturvedi (2011). The isolated strain was carried out for resistance to Cr (VI) and its ability to remove Cr (VI). The strain was found to tolerate Cr (VI) concentration as high as 4500 mg/L, but the cell growth was heavily influenced when initial Cr (VI) concentration was increased between 1110 mg/L and 4500 mg/L while Cr (VI) at 500 mg/L to 1110 mg/L did not suppress the cell growth. Series experiments in this study demonstrated that the cells removed toxic Cr (VI) more efficiently at 30°C compared with that at 25°C and 35°C. The optimum initial pH for Cr (VI) removal was 5.6 and final pH values of 5.1-5.6 were observed for initial pH 5.2-5.7. A comparative study done by Dermentzis et a.l (2011) found that the removal of hexavalent chromium from synthetic aqueous solutions and actual industrial electroplating wastewater by using iron electrodes. The parameters affecting the electrocoagulation process, such as initial pH, applied current density, initial metal ion concentration, COD and time of electroprocessing were investigated. The optimum pH was found to be in the range 4-8. Initial chromium concentrations of 200 – 800 mg L-1 did not influence its removal rate. Higher concentrations were reduced significantly in relatively less time than lower concentrations. Increased current density accelerated the electrocoagulation process, however, on the cost of higher energy consumption. Results revealed that best removal was achieved at a current density 40 mA cm-2. The electrocoagulation process was successfully applied to the treatment of an electroplating wastewater sample. Its Cr (VI) ion concentration and COD were effectively reduced below the admissible limits in 50 minutes of electroprocessing . According to Merzouk et al.(2011) the efficiency of electrocoagulation (EC) for the abatement of COD, TOC, absorbance (I.e.color) and turbidity from a real textile wastewater, a pure red dye solution (disperse dyes 2naphthoic acid and 2-naphthol) and a solution combining the two above fluids. The treatment of the dyestuff solution is satisfactory with high levels of color and organic pollution abatement. The treatment of the industrial waste is less efficient. Treatment of the solution combining the two above fluids allows to investigate whether the removal of several polluting matters by electrocoagulation could be considered as the superimposition of the various treatments of single-species effluents, in a sort of additivity principle, as presented in an original model for the treatment of two-pollutant waste. Turbidity and TOC were shown to be additive variables in the treatment of the dye solution and the industrial textile waste: electrocoagulation seems to proceed with no interaction

II. MATERIALS AND METHODS

A. Hospital Effluent

Operation theatre effluent was collected from a hospital located in Palakkad. The effluent was characterized and the results. It can be noticed that the COD, a measure of organic strength of wastewater, is quite high and the effluent needs treatment before being discharged. This is due to the fact that hospital wastewater contains blood and other body fluids, which are mainly organic molecules like proteins, fats and glucose. The COD of the supernatant sample was determined by the dichromate method (open reflux, titrimetric method) (APHA: 5220B). The conductivity of the solution is an important operational parameter in the process of electrocoagulation and salts are added to the solutions having low conductivity for the flow of current. But the addition of the salt leads to an increase in the total solids of the solution.

B. Experimental Set-Up

Experiments were performed in a glass beaker in batch mode of operation using Fe-Fe combination of electrode. The dimensions of the electrodes were 100 mm × 20 mm × 1 mm (length × width × thickness). The electrode was dipped 3 cm in the solution and the submerged area of the electrode in the solution was 6cm^2. The electrodes were connected to a DC power supply, providing 0-30 V (0-3 Amp). The contents in the beaker were agitated by a magnetic stirrer (SPINOT 02, India) to avoid concentration gradient and maintain uniform concentration in the beaker. After a fixed electrolysis time, the contents of the beaker were allowed to settle for a fixed retention time of 30 minutes. The sludge was separated and the COD of the supernatant liquid was determined. The COD removal efficiency was determined using the following equation: COD removal efficiency (%) = [(Initial COD of the sample – COD of the sample after electrocoagulation) / Initial COD of the sample] x 100

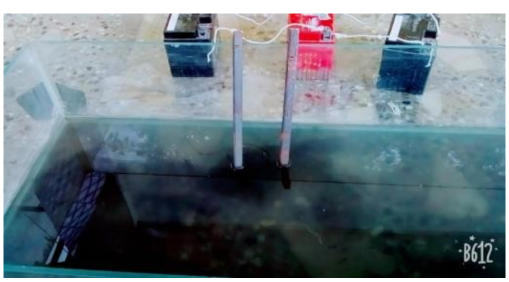

Fig No.1 Experimental Set-Up

III. RESULTS AND DISCUSSIONS

Electrocoagulation experiments were conducted in batch mode of operation for the treatment of hospital operation theatre effluent using different combinations of electrodes. The effect of various operational parameters on COD removal efficiency was investigated. The test was conducted on basis of test methods of IS 3025.

Effect of electrode spacing

The distance between the electrodes is an important parameter in the removal of pollutant by electrocoagulation. The experiments were performed by maintaining different distances (1-3 cm.) between the electrodes. The current density was kept constant at 12.2 mA/cm^2. The agitation speed was 300 rpm and the electrolysis time was 30 min. It was not possible to maintain the inter-electrode distance lower than 1 cm due to the experimental limitations. The maximum removal efficiency was obtained with Fe-Fe electrode. The higher removal efficiency achieved by Fe -Fe electrodes is due to the fact that the pH of the effluent was acidic (6.64) that thermodynamically favored the overall oxidation of Fe to Fe^{3+} ions. Generated Fe^{3+} ions at the anode combine with the OH^- from the cathode and produce ferrous hydroxide as a coagulant, which leads to the sedimentation of the pollutant. The results are in agreement with those reported in the literature for reducing COD of a paper mill effluent. It can be noticed that the COD removal efficiency decreases with an increase in the spacing between the electrodes from 1 cm to 3 cm. This is due to the fact that an increase in the electrode spacing decreases the electrostatic effects resulting in a slower movement of the generated ions. The lower mobility of the ions requires more time to aggregate, leading to the reduction in the formation of flocs. The results are in agreement with those reported in the literature .Since it was not possible to perform experiments with inter-electrode distance lower than 1 cm due to experimental limitations, the optimum electrode distance was taken as 2cm and all further experiments were conducted by maintaining the inter-electrode distance as 2 cm.

Fig No. 2Electron dipped in Wastewater

Effect of current density

Another important parameter in the EC process is current density, since it affects the performance and operating cost of the system. Experiments were performed by varying the current density between 1.1 mA/cm^2 to 14.4 mA/cm^2. The agitation speed was kept constant at 300 rpm and the electrolysis time was 30 min. It can be noticed that the COD removal efficiency increases with an increase in current density upto 12.2 mA/cm^2. No increase in COD removal efficiency was observed on further increasing the current density from 12.2 mA/cm^2 to 14.4 mA/cm^2. This is due to the fact that with an increase in the current density, there is an increase in the anode dissolution rate. The enhanced anode dissolution rate increases the concentration of metal ions in the solution leading to an increase in the quantity of flocs formation. The flocs lead to the removal of pollutants via sedimentation resulting in an increase in removal efficiency. Moreover, the increase in current density results in formation of more gas bubbles due to the generation of hydrogen at the cathode, which cause greater upward flux, and faster removal of pollutants by flotation. No increase in COD removal efficiency was obtained beyond a current density of 12.2 mA/cm^2 as sufficient quantity of flocs was available for the sedimentation. It should be noticed that the effluent contains lighter particles such as oil and grease, which floats on the surface of the solution after electrocoagulation and can be easily removed by floatation. The optimum current density was found to be 12.2 mA/cm^2, which resulted in COD removal efficiency of 80.55 % for an electrolysis duration of 30 min.

Effect of agitation speed

Experiments were performed to study the effect of agitation speed on COD removal efficiency by conducting experiments with different agitation speeds. The current density was kept constant at 12.2 mA/cm^2 for an electrolysis time of 30 min. The experiments were conducted using Fe-Fe combination of electrodes by maintaining an electrode distance of 2cm. Initial experiment was performed without any agitation. It can be noticed that the COD removal efficiency increases initially, reaches a maxima and then decreases with a further increase in the agitation speed. The agitation helps in maintaining the uniform concentration inside the beaker. Moreover, an increase in the agitation speed enhances the mobility of the ions leading to the formation of flocs, which are responsible for the sedimentation of the pollutant. But an increase in the agitation speed beyond the optimum value leads to the destabilization/breakage of flocs resulting in the reduction in the COD removal efficiency. It can be noticed that the COD removal efficiency obtained at 300 rpm is lower as compared to the COD removal efficiency of the experiment without agitation. In the present study, 300 rpm was found to the optimum agitation speed for all the electrode combinations and further experiments were performed at 300 rpm

Effect of electrolysis time

The effect of electrolysis time on agitation speed was studied by performing experiments with different electrolysis durations and the results are shown. It can be noticed that COD removal efficiency increases with an increase in electrolysis time and finally becoming constant after a certain time. This is due to the fact that with an increase in the electrolysis time, there is an increase in the number of ions leading to an increase in the quantity of flocs. Since 80.55 % COD removal efficiency was obtained for an electrolysis duration of 30 min.

TABLE I

Characteristics of hospital effluent before Electrocoagulation

Parameters	Values
pH	6.50
TOTAL SUSPENDED SOLIDS	15mg/l
TOTAL DISSOLVED SOILIDS	949mg/l
B.O.D(3days at 27^{o}C)	110mg/l
COD	504mg/l
TURBIDITY	6NTU

TABLE II

Characteristics of hospital effluent after Electrocoagulation

Parameters	Values
pH	6.64
TOTAL SUSPENDED SOLIDS	10mg/l
TOTAL DISSOLVED SOILIDS	936mg/l
B.O.D(3days at 27^{o}C)	16.3mg/l
COD	98mg/l
TURBIDITY	3NTU

IV. Conclusions

In the present study, the performance for electrocoagulation treatment of hospital wastewater was studied focusing on the influence of operating condition (current, electrocoagulation time and pH) by using response surface methodology. The statistical analysis shows that all the variables used in the preparation of model for the treatment of hospital wastewater 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 found are current (3A), electrocoagulation time (60minutes) and pH (6.64).The actual COD removal and electrode consumption at optimized conditions are 80.55% and 1.78 gL-1respectively. The actual COD removal and electrode consumption are close to the predicted response. Hence, the results of this study show that electrocoagulation is an effective method for treatment of Hospital wastewater. Experimental study was carried out to explore the feasibility of electrocoagulation for the treatment of hospital effluent. The effluent was characterized and was found to have high COD content. The experiments were performed in batch mode of operation using Fe-Fe combination of electrode and the results were tabulated in terms of COD removal efficiency. The Fe-Fe electrode combination resulted in the higher COD removal efficiency. A 80.55% COD removal efficiency was obtained using Fe-Fe electrodes for an current density of 12.2 mA/cm^2 for an electrolysis duration of 60min. The results demonstrated that electrocoagulation can be used for the treatment of wastewater.

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