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Optimization of treatment of dairy wastewater by electrocoagulation technique

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ABSTRACT

The aim of this research was to optimize the operating parameters in electrocoagulation process such as voltage, electrode distance and time for the removal of chemical oxygen demand (COD), biological oxygen demand (BOD) and total suspended solids (TSS) from dairy wastewater. The results showed that the optimized conditions were voltage of 25V, electrode distance of 3 cm and time of 45 min. Under the conditions, the removal efficiency of COD, BOD and TSS were 86%, 84% and 82% respectively.

KEYWORDS

Dairy industry wastewater;
Electrocoagulation;
Current;
COD removal;
Optimization.

INTRODUCTION

The large quantity of aqueous waste generated by domestic activities and industries has becomes a significant environmental problem in worldwide due to its harmful nature. In dairy industries, water has been a key processing medium. Water is used throughout all steps of the dairy industry including cleaning, sanitization, heating, cooling and floor washing and naturally the requirement of water is huge[1]. Dairy wastewater is distinguished by the high BOD and COD contents, high levels of dissolved or suspended solids including fats, oils and grease, nutrients such as ammonia or minerals and phosphates and therefore require proper attention before disposal. The wastewater is generally a mixture of milk or other dairy products diluted with water. Containing high level of organic materials, dairy industry wastewater is considered to be one of the most contaminated wastewater and purification of the same has always been challenging. Thus many research studies have been conducted with this aim[2].

Dairy wastewater includes industrial waste, flushing waste and waste from aqueous cooling systems. Industrial waste may originate from washing milk carrying and storing containers, bottles and glasses, sterilizing depositories, delivery station floors and other installations present, such as, pumps, boilers, etc. Waste in pasteurization and sterilization units is mainly composed of machine coolants. Receiving waters can be affected by diary wastewater with an increased rate of dissolved oxygen depletion, a decrease in the pH level due to the conversion of lactose to actic acid in the fermentation process, an increase of casein bed deposit at acidic pH values, an increase in fungal growth due to a pH

drop, a destruction of marine life due to the entry of cleansers and detergents from the cleaning process[3].

A variety of different treatment processes is being currently practiced such as; physical and chemical processes, trickling filters, activated sludge, rotating biological disc contactors, dissolved air flotation and anaerobic purification lagoons. Due to high COD removal and sludge production expenses, as well as high energy costs, the electrochemical treatment of dairy industry wastewater has grown in importance. Electro-coagulation is the process of destabilizing suspended, emulsified or dissolved contaminants in an aqueous medium by introducing an electrical current into the medium during which the

Figure 1 : Image of electrocoagulation experimental setup

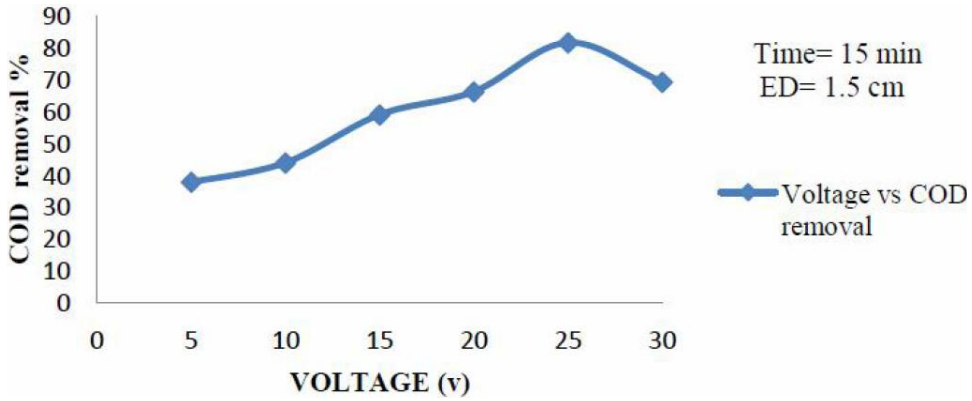


Figure 2 : Preliminary analysis of Voltage vs COD removal

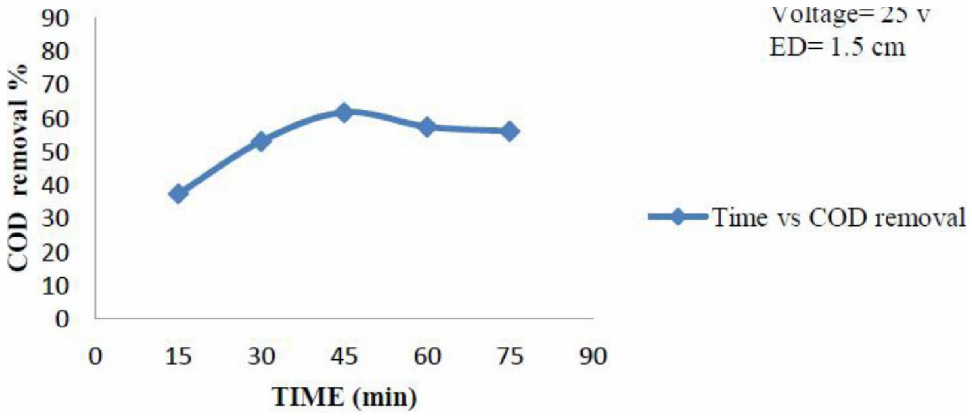


Figure 3 : Preliminary analysis of time vs COD removal

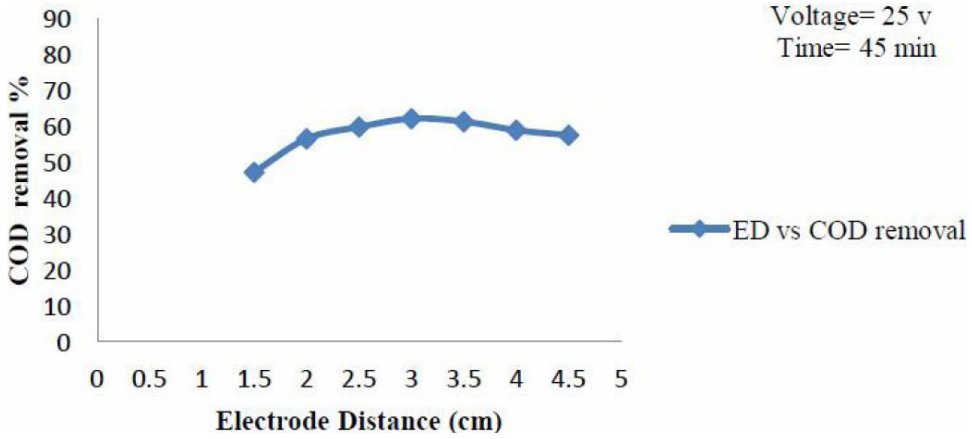
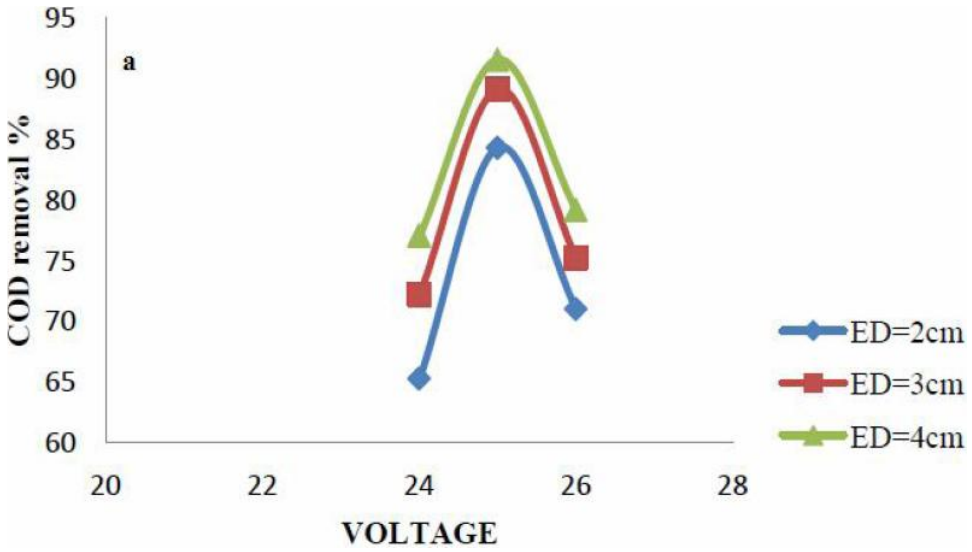


Figure 3a : Preliminary analysis of electrode distance (ED) vs COD removal



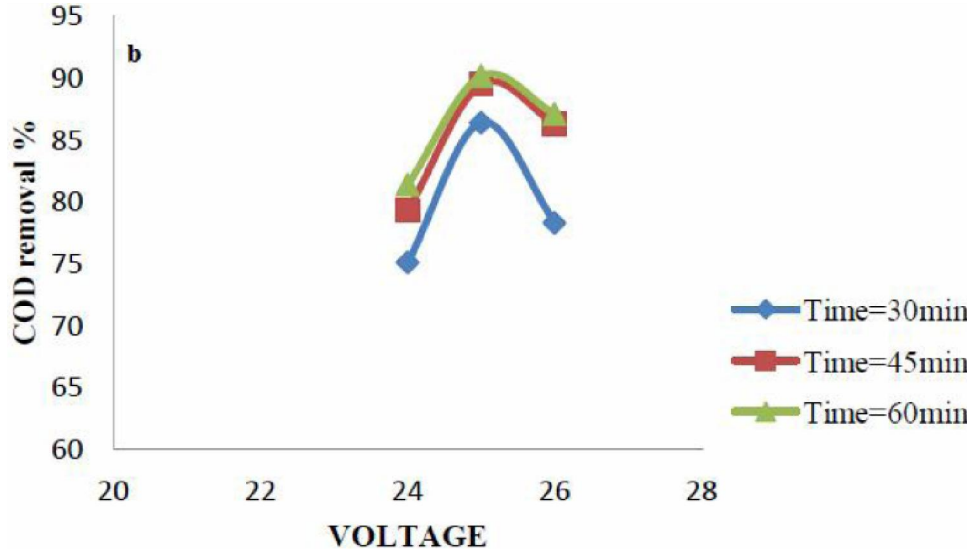


Figure 4 : Effect of voltage with other parameters for COD removal

surface charge of the colloidal particles reduces to a point where they can overcome the vandervalce forces in between and allow coagulation to occur[4]. The electrochemical process is characterized as being easy to use, having simple equipment, being easy to operate, having a good settling ability of produced

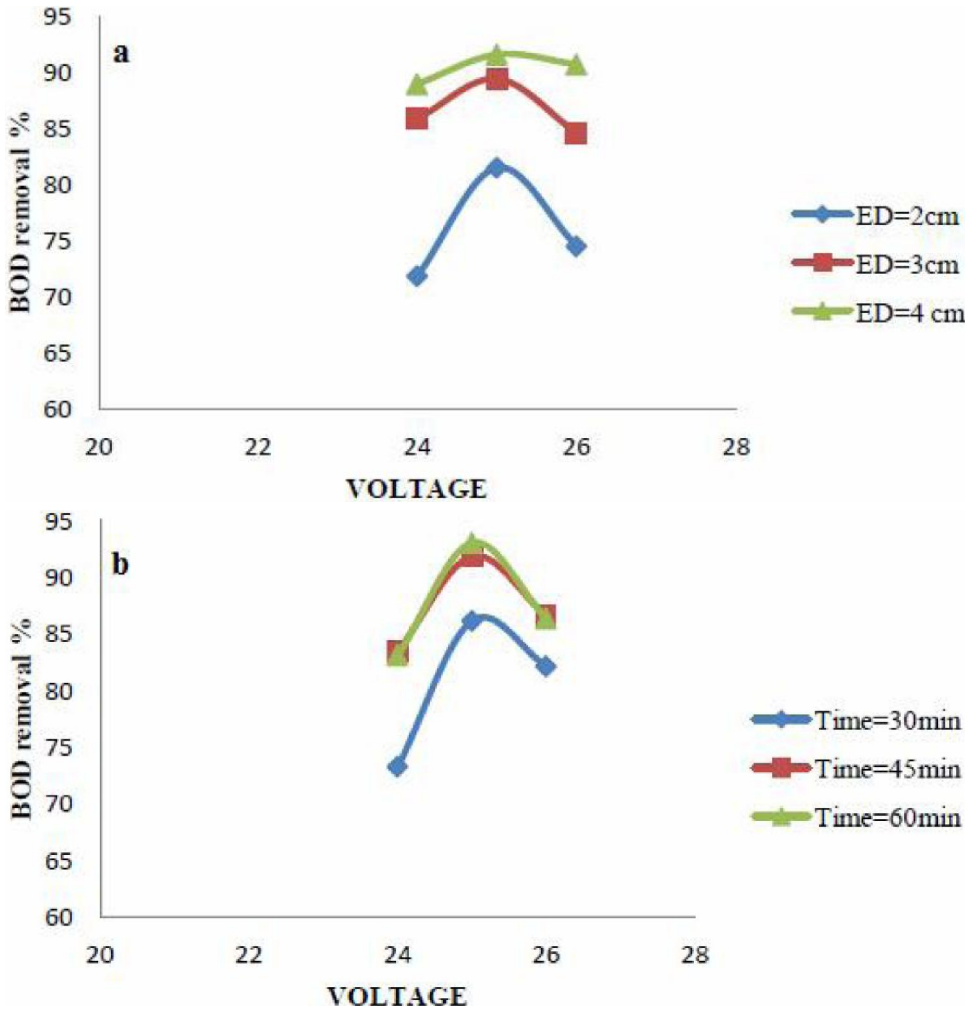


Figure 5 : Effect of voltage with other parameters for BOD removal

sludge, and being able to reduce operating costs and to lower TDS in the wastewater compared with standard chemical procedures. This procedure is used in the treatment of wastewaters from the dairy industry, textile industry, restaurants, laundries, municipalities and alcohol distillation plants. The three main processes occur serially during EC which are[5]:

(a) Electrolytic reactions at electrode surfaces.
(b) Formation of coagulants in the aqueous phase.
(c) Adsorption of soluble or colloidal pollutants on coagulants, and removal by sedimentation or floatation[6].

An extensive literature survey shows that, there was no research reports are available on the treatment of dairy industry wastewater using electrocoagulation process, which may be give the crucial solution to environmental related problems. Hence the present has been made to investigate the individual and interactive effect of process variables such as voltage, electrode diatnce and treatment time on the percentage removal of chemical oxygen demand (COD), biological oxgen demand (BOD) and total suspended solids (TSS) from dairy industry wastewater.

MATERIALS AND METHODS

Raw wastewater and chemicals

Wastewater from dairy industry was collected from dairy industry and stored at refrigerated conditions. Initial characteristics of the wastewater were analyzed. The charcterstics of wastewater was found to be: initial pH of 5.2, COD of 3312 ppm, BOD of 1140 ppm, TSS of 1000 ppm and Total hardness of 1020 ppm, respectively. The pH, COD, BOD, Total

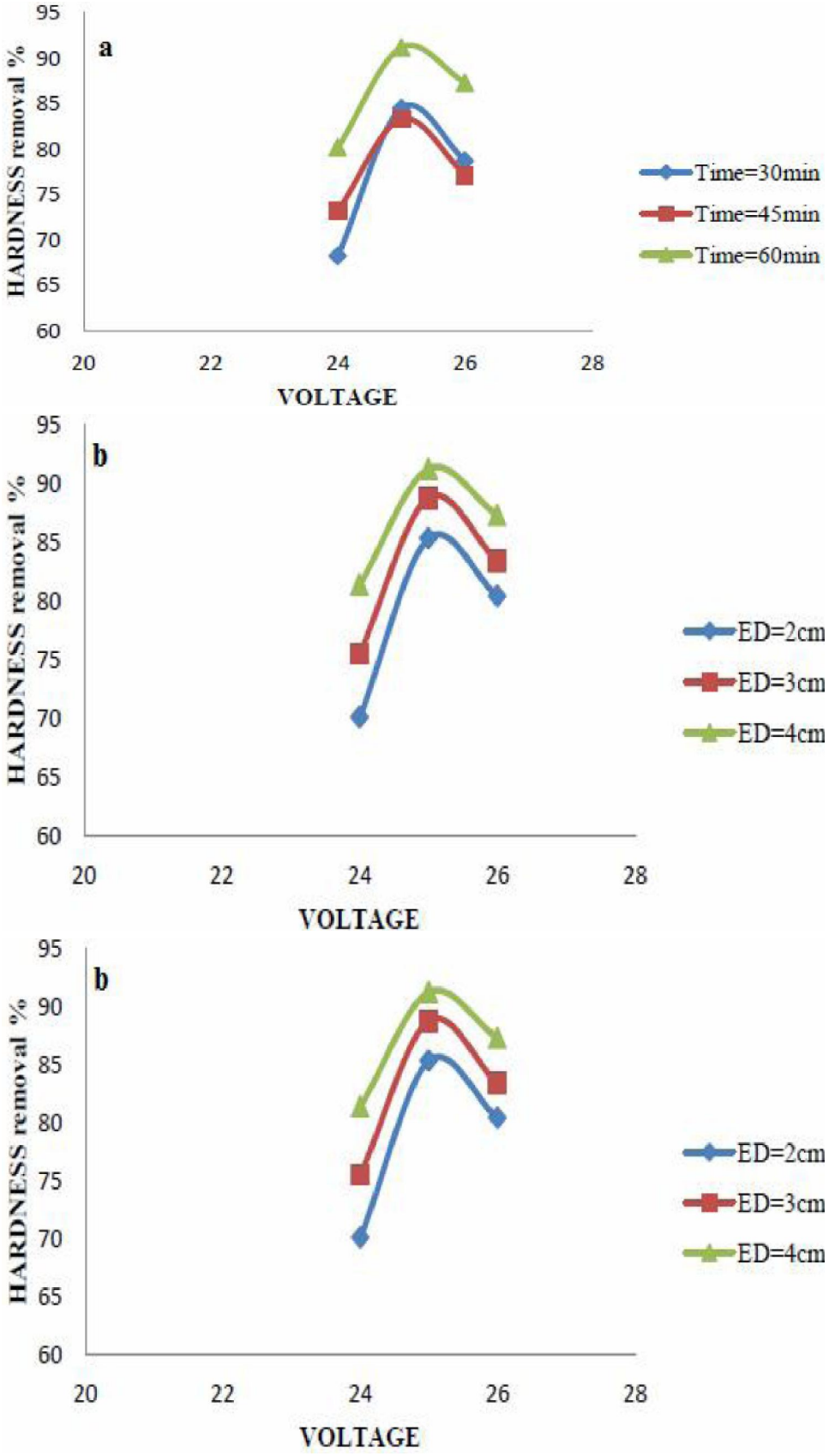


Figure 6 : Effect of voltage with other parameters for HARDNESS removal

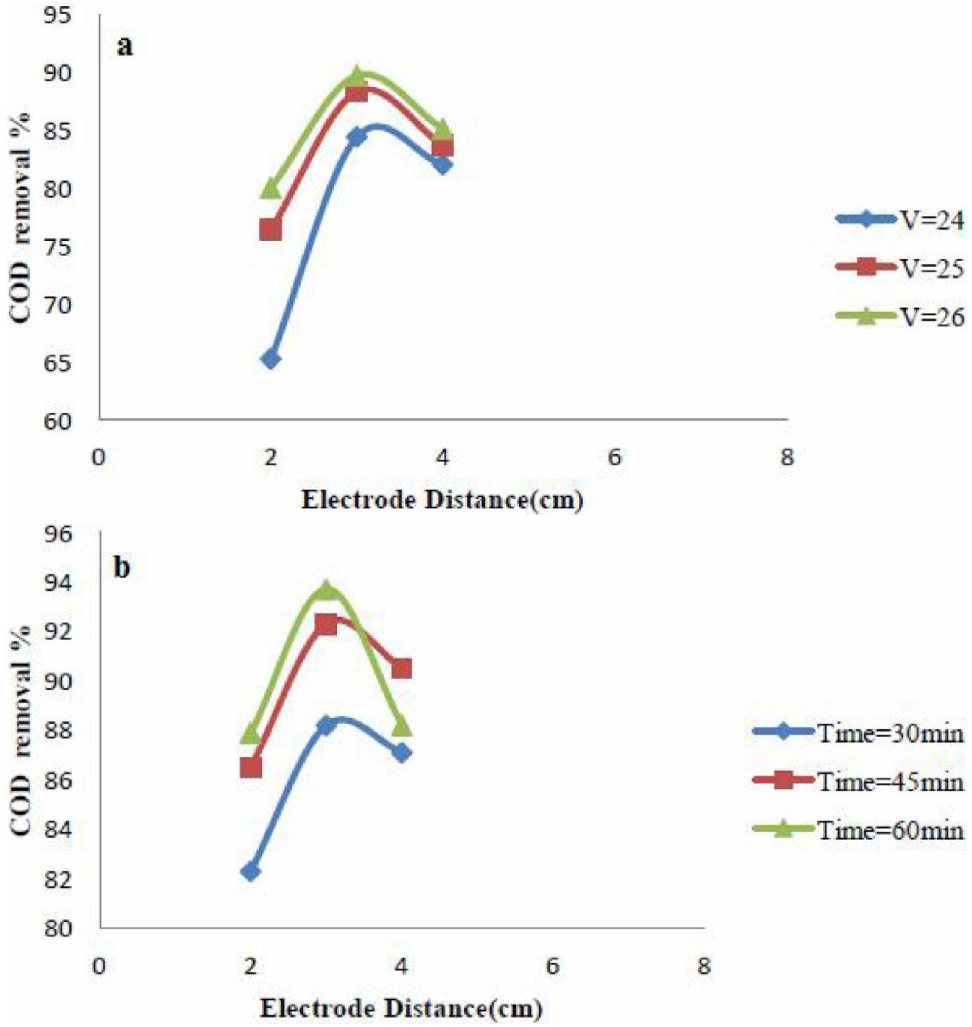


Figure 7 : Effect of electrode distance with other parameters for COD removal

Hardness and TSS analysis were carried out by methods described by American Public Health Association[7]. All the chemicals (HCl and NaOH) used in this study were anlaytical grade and purchased from local suppliers from Erode, TamilNadu.

Experimental method

Electro coagulation consists of pairs of metal sheets called electrodes, that are arranged in pairs of two—anodes and cathodes. Using the principles of electrochemistry, the cathode is oxidized (loses electrons), while the water is reduced (gains electrons), thereby making the wastewater better treated. When the cathode electrode makes contact with the wastewater, the metal is emitted into the apparatus. When this happens, the particulates are neutralized by the formation of hydroxide complexes for the purpose of forming agglomerates. These agglomerates begin to form at the bottom of the tank and can be siphen out through filtration. Image of electrocoagulation experimental setup was shown in Figure 1.

Analytical method

The removal efficiency (RE) was calculated by using the following equation[8]

$$RE = \left(\frac{c_0 - c_e}{c_0} \right) \times 100 \quad (1)$$

where, c_0 and c_e is the initial and final concentrations of pollutants.

RESULTS AND DISCUSSIONS

Preliminay studies

Preliminary studies are done whether the electro coagulation method is suitable for treatment dairy

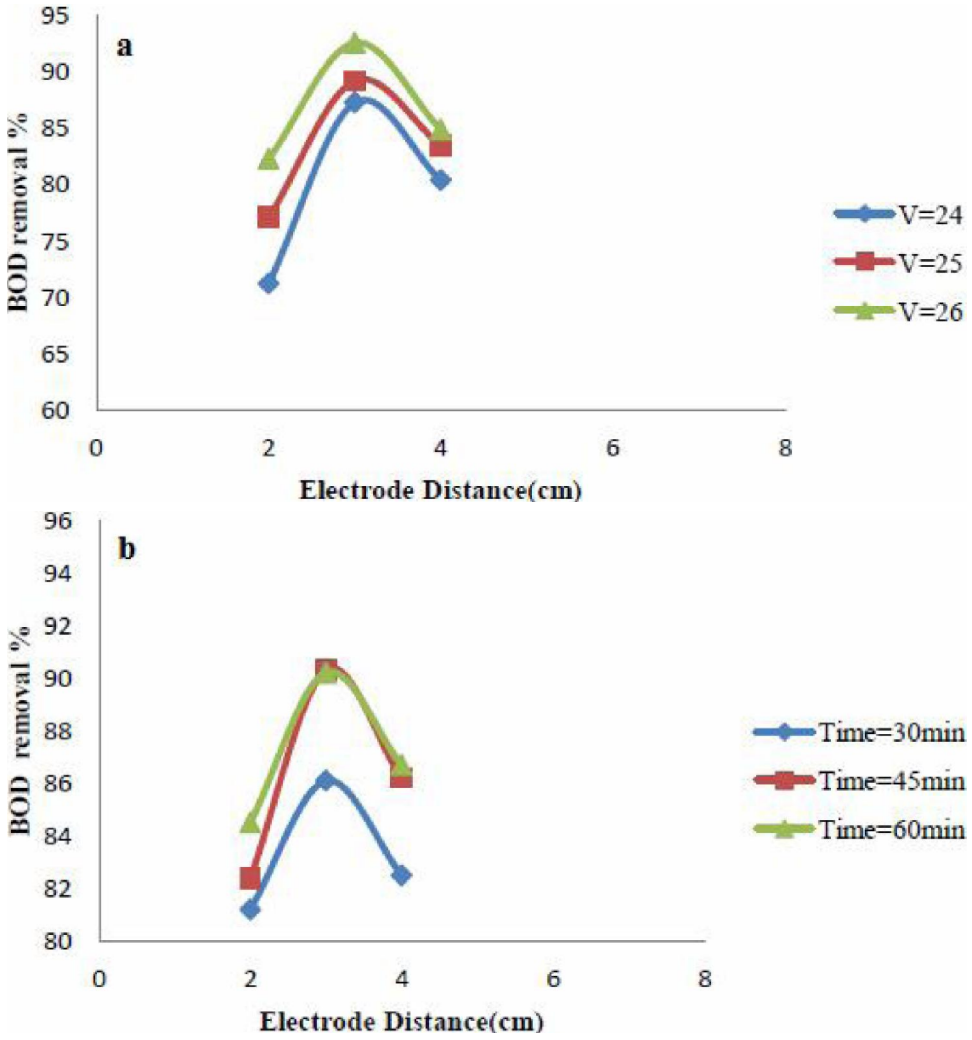


Figure 8 : Effect of electrode distance with other parameters for BOD removal

wastewater. It is used to identify the range where the efficiency of removal is high. From the preliminary studies (Figure 2 to Figure 4) we analyze that all parameters have a considerable effect on treatment of wastewater by electro coagulation method. For voltage the maximum COD removal is obtained in the range 24-26v. The treatment efficiency increases with increase in time till 45 min after that it tends to reach stable condition. Hence the time range if fixed as 30-60 min. For electrode distance the amount of COD removal increases with increase in distance. Decrease in distance leads to ion diffusion and colour change. Finally the range of maximum removal is obtained between 2-4cm respectively[9-10].

Optimisation

Voltage Optimisation

Effect of voltage with other parameters for the removal of COD is shown in Figure4-4a.

The maximum removal of COD is obtained at the voltage 25. At this voltage optimum removal of COD takes place. After that increase in voltage leads to decomposition and colour changes takes place. This discoloration occurs due to the short circuit of electrodes due to increase in voltages. it can't able to withstand the increasing voltage it leads to the decrease in removal. hence the curve became declined after certain voltage limit[11-13].

Above figure shows the effect of voltage with time and electro distance variation. The maximum BOD removal is obtained at voltage 25. After that the decrease in BOD level. so that decomposition of metal takes place and foam formation occurs[14-15].

The effect of voltage with other parameters for

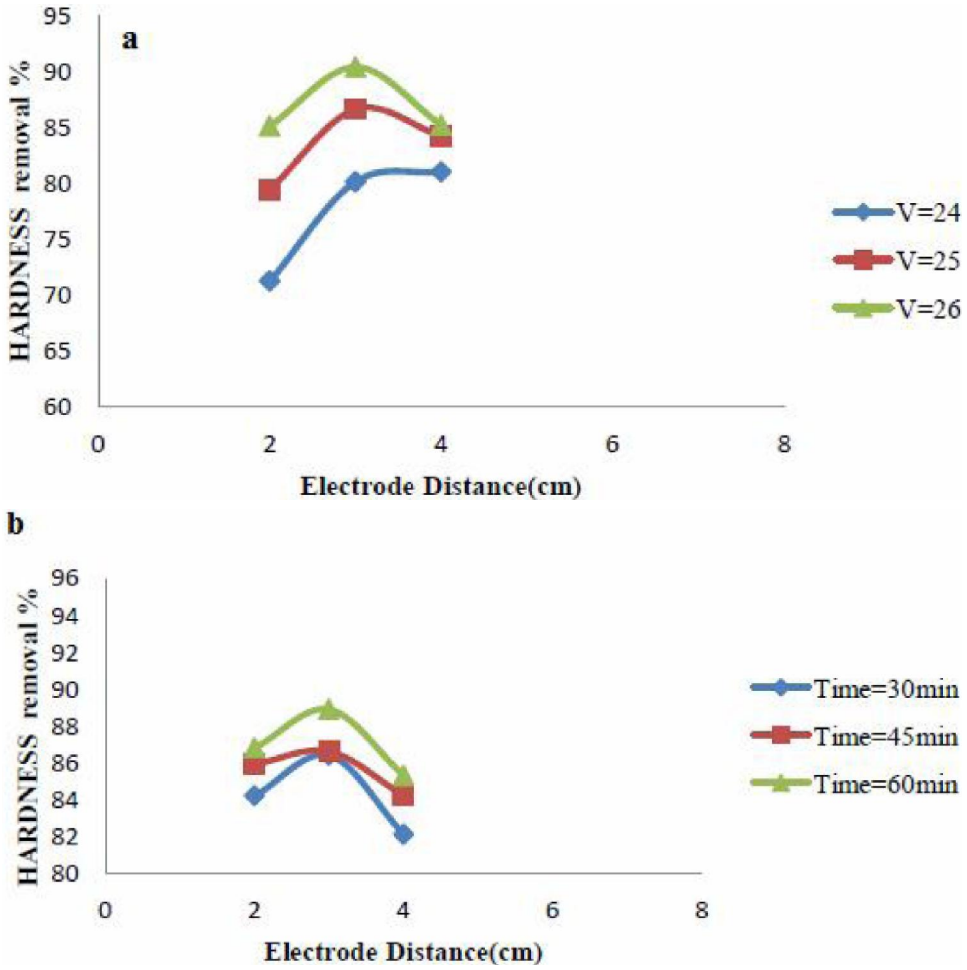


Figure 9 : Effect of electrode distance with other parameters for HARDNESS

HARDNESS removal is shown in Figure-6. The maximum removal is obtained in voltage 25. From this, voltage 25 is taken as optimum for the electro coagulation method for treatment of dairy wastewater. The decrease in voltage gives proper separation of effluent but increase in voltage above 25 leads to decomposition which reduces the efficiency of the treatment.

Electrode distance optimisation

The removal of COD gradually increases with varying the voltage and distance. At a point of distance 3, it attains the maximum removal. After that the curve is slightly declined due to the increase in voltage. The reason behind this is when the voltage increases electric charged ions gets accelerated which passes over the electrodes create damage to the circuit.

Electrode distance plays a major role for electro coagulation treatment. If the distance is reduced there might be short circuit between the electrodes and efficiency will be low. Hence electrode distance is increased for efficiency (Figure 7). Due to increase in electrode distance removal efficiency increases and also the electric resistance and voltage increased with the increase of the electrode distance, which caused higher energy consumption[16-17].

From this Figure.8,9 the electrode distance 3 gives the maximum removal of BOD. As time increases removal efficiency will be high large amount of corrosion takes place in electrodes due to increase in time which gives high removal efficiency. The maximum HARDNESS removal is obtained at the electrode distance 2 cm. From this figure the distance 2 cm is optimized which gives high removal efficiency.

Removal

Time optimisation

The efficiency of the electro-coagulation treat-

ment increases with increases in time. But the efficiency reaches a stable value at a particular period of time. After that COD removal is very low. From the graph we get a conclusion that upto 45 min there is increase in COD removal and after that time there is slight change in removal of COD (Figure 10).

The BOD removal is maximum at the time of 45 min. From the Figure 11 we conclude that there is slight decrease in BOD removal when time is increased. According to Faraday's law the electrolysis time determined the total amount of Fe3+ and Fe2+ ions produced during the electrochemical process and subsequently affect the pollutant elimination efficiencies[18-19].

From the Figure 12 the removal of hardness is maximum at 45 min. After that the removal efficiency

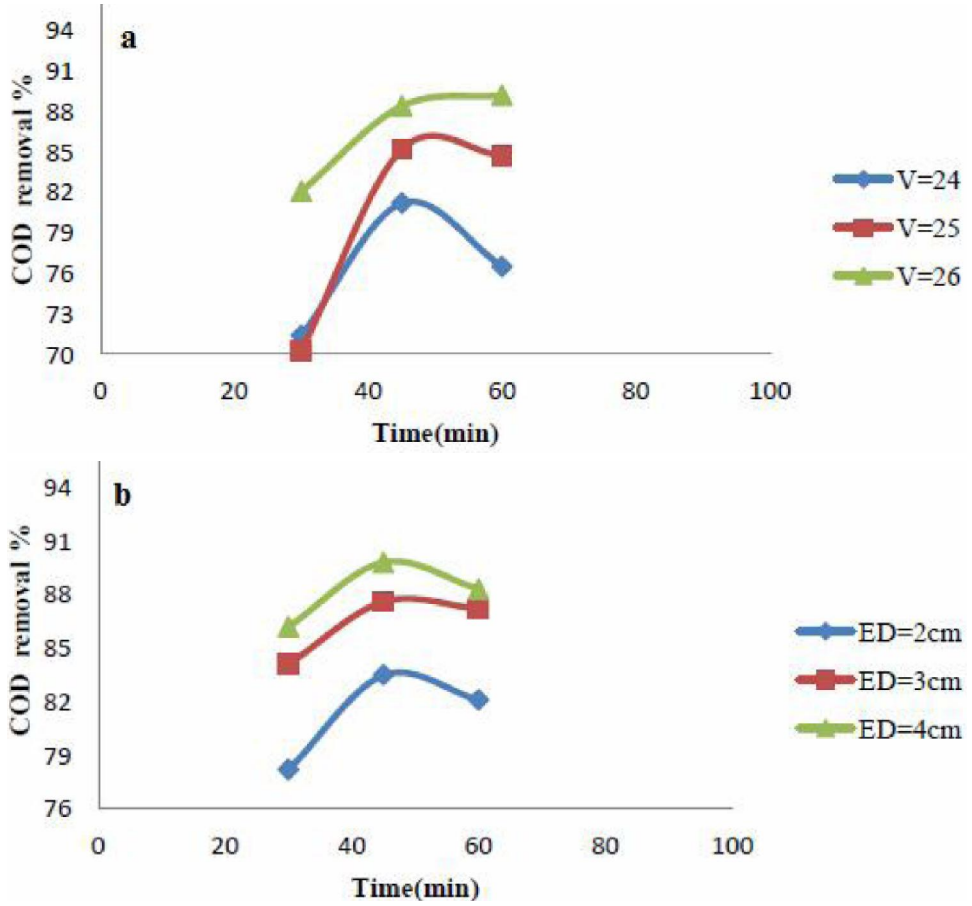
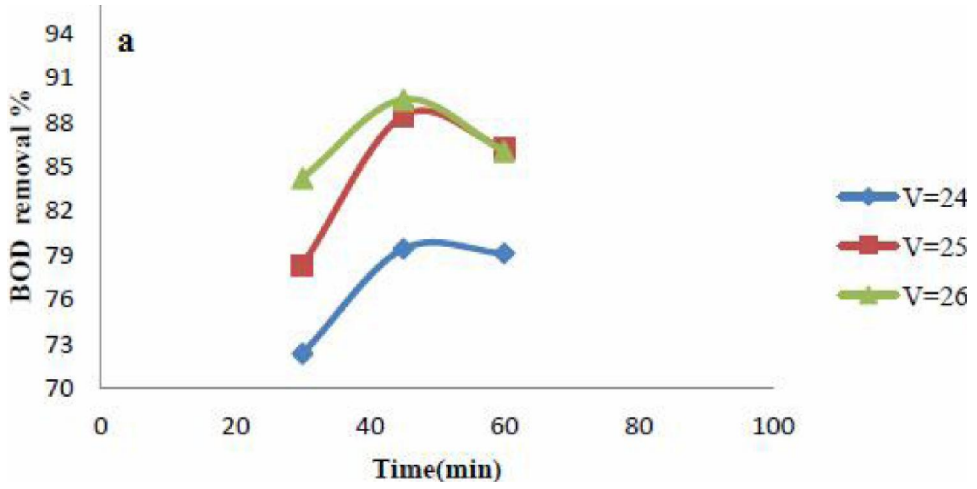


Figure 10 : Effect of Time with other parameters for COD removal



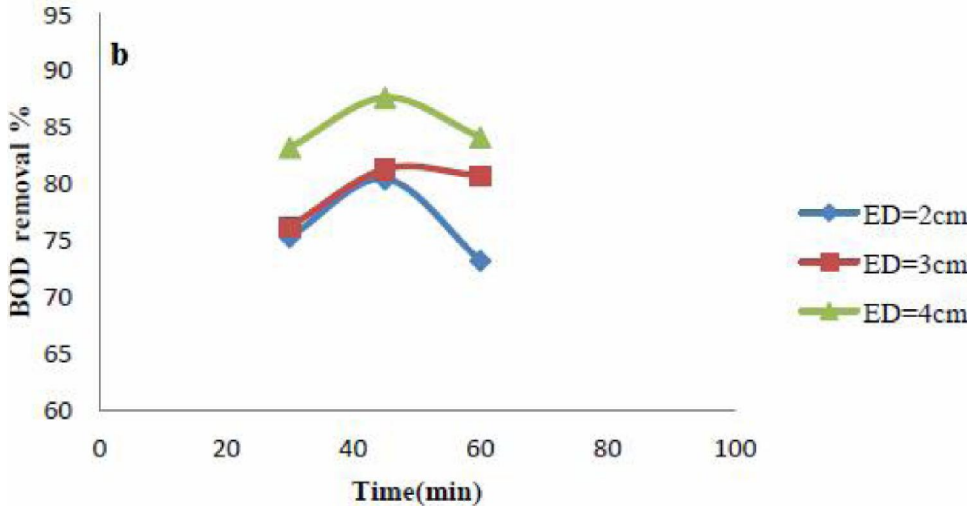


Figure 11 : Effect of time with other parameters for BOD removal

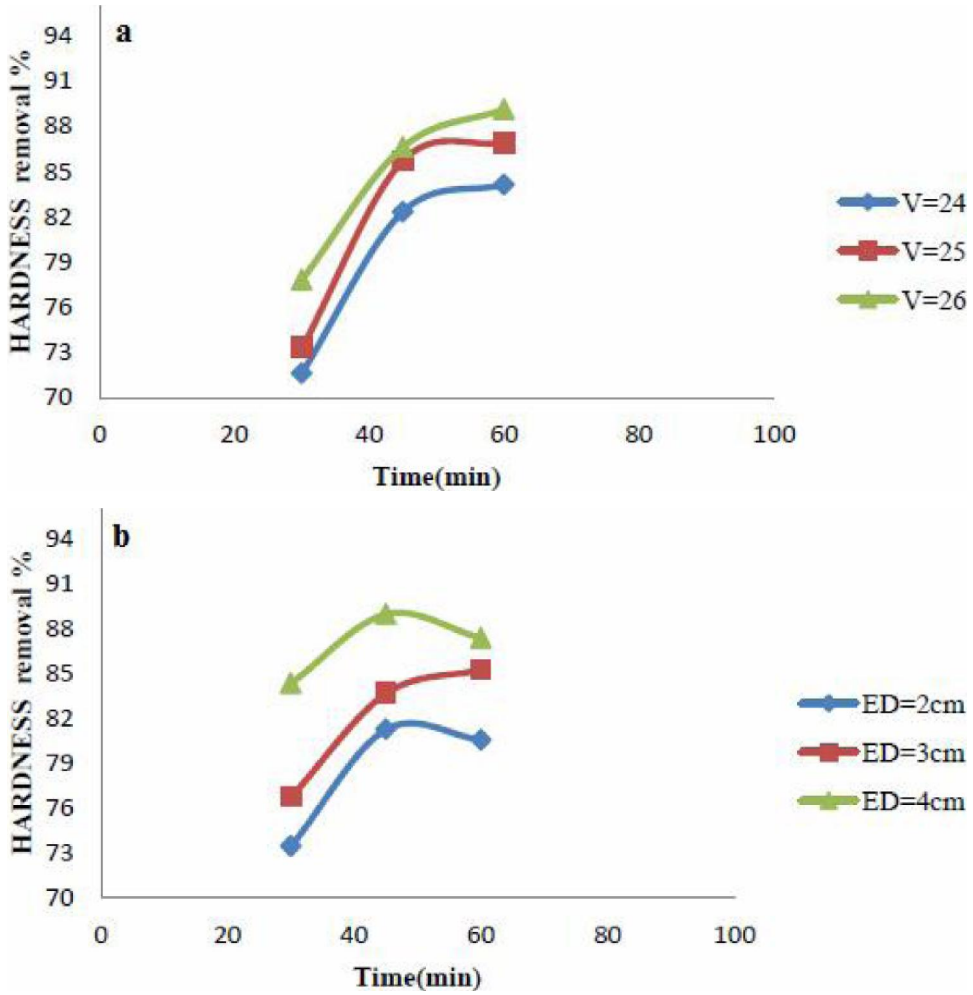


Figure 12 : Effect of Time with other parameters for HARDNESS removal

become linear with increase in time. Finally we conclude that 45 min is optimum time for electro-coagulation method.

Optimization of process parameters s

The results showed that the optimized conditions were voltage of 25V, electrode distance of 3 cm and time of 45 min. Under the conditions, the removal efficiency of COD, BOD and TSS were 86%, 84%

and 82% respectively.

CONCLUSIONS

This investigation shows that electro coagulation method can be successfully applied to the treatment of dairy wastewater with minimal sludge production. The sludge production is not high in this method. During primary characterization the values are very high and after treatment there is maximum reduction of pollutant value in the dairy sample. For BOD value, 84.21% reduction takes place and COD reduced to 85.8%. The hardness is reduced to 82.84%. Further we tested for protein recovery in the dairy sample but it contains minimum amount of protein. It has the value of 0.2625 mg/L. So the recovery of protein from the wastewater is not feasible as it increases the cost of recovery.

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