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Performance of Electrocoagulation Technique for the treatment of Dairy Wastewater in a Batch Process

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Abstract: ***The treatment of dairy industry effluent was researched in an electrocoagulation reactor run at batch mode with Stainless Steel (SS 304) and Aluminium electrodes showing eventual and gradual deterioration. The impact of operating parameters such as change in the material of electrode, distance between the electrodes, electrolysis time, variation in the input of voltage, speed of rotation of the stirrer etc on the percentage removal of chemical oxygen demand and biochemical oxygen demand was evaluated. The optimum results of the experimentations were obtained with speed of rotation at 150 rpm, keeping the distance between the Stainless Steel (SS 304) electrodes as 2 x 10^{-2} meter, maintaining the pH of 7-8 and performing the experimentation for 4 hours. The average of all the similar sets of experimental conditions with these optimum parameters resulted in the best percentage removal for the chemical oxygen demand and biochemical oxygen which was investigated to be 92% and 86% respectively. Since the electrolysis time of 4 hours was employed for the process to get completed, the consumption of electricity was observed to be in the range of 16 - 64 KWh/m^3. Therefore, depending on the observations and results obtained in the analysis, the best fit suitable data is presented in this paper as a behavior of parameters with respected to operating conditions.***

Keywords: Batch mode, Chemical oxygen demand, Biochemical oxygen demand.

1. Introduction

Dairy industry is one of the extensive industries that produce the effluent in voluminous amount, at least in developing countries, on daily basis. The effluent expelled by raw milk quality control laboratories are more complicated (structure wise) than the ones that is generated by diary factories because of the addition of the certain chemicals such as sodium azide or chloramphenicol that are used for preserving milk before analysis. The environmental effect of these factories can be very intensive, principally because of the discharge of large streams of wastewater with copious content of organic matter and metallic constituents (nitrogen and phosphate). Dairy is having specific properties of effluents and therefore has the different effluent related problems. Different types of operations in the dairy industry are bottling, pasteurization, preparation of flavored milk, butter, yoghurt, cheese, milk powder, buttermilk etc. Effluent from dairy industry mainly contains dilution of milk and its products which cause a very high BOD_5, occasionally observed up to 1100 mg/L. The waste water may also contain surfactants, detergents, germ killing and other preservative chemicals. Reuse of wastewater has become an absolute need so that there is an immediate need to develop innovative, more competent, and low-cost techniques for treatment of wastewater (Feng et al., 2003). The Environmental protection agency of United States has established that dairy wastewater problem caused by defective sewage management result into a considerable health and environmental challenge as the sewage into streams, before it can reach a treatment centers. The Maharashtra Pollution Control Board, India, has advised the industries to invoke the technology that has almost zero discharge of pollutants.

From an environmental perspective, most of the waste water treatment processes is still far from being environmentally sustainable. Based on a theoretical study, a structural approach is given on how to accomplish a better sustainable treatment process. Some of the possibilities are the advancement of the decreasing the toxic pollutants, sludge treatment processes with high-temperature involvement, and membrane separation processes (Rulkens, 2006). Therefore, electrochemical treatment appears to be an assuring treatment approach because to its high performance, its lower maintenance cost, lesser need for labor and fast achievement of results (Feng et al., 2003). A host of assuring techniques based on electrochemical technology is being designed, and current ones are being upgraded that do not require chemical inclusion (Mollah et al., 2001). Electro-coagulation–flotation treatment is researched as the one having outstanding ability for the removal of COD and SS from effluents as compared to the treatment by traditional coagulation (Jiang et al., 2002). Electrocoagulation can be used to get rid of silicates, irons, humus, dissolved oxygen (Chen, 2004) and reduce copper (Comninellis et al., 1993). Electrocoagulation has also been adapted profitably to treat urban wastewater, restaurant wastewater, nitrate containing wastewater, potable water, chemical and mechanical polishing wastes, food, and protein wastewater, yeast wastewater, tar sand, and oil shale wastewater, heavy metals, organic matter from landfill leachate, textile dyes, fluorine, polymeric wastes, suspended particles, aqueous suspensions of ultrafine particles, and phenolic waste (Mollah et al., 2004). Elimination mechanisms of the Electrocoagulation process include coagulation, adsorption, precipitation, and flotation (Kobya et al., 2003). Therefore, currently, Electrocoagulation techniques are more economic and more compact.

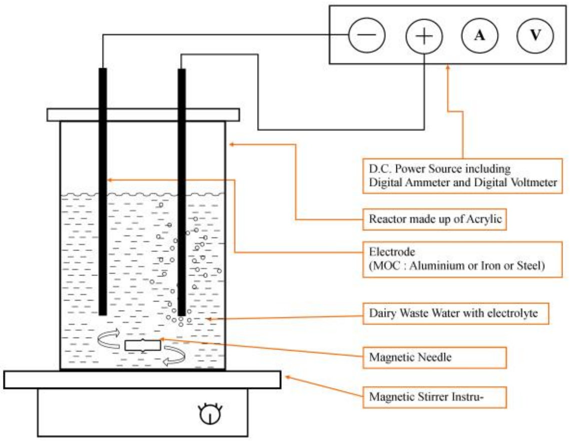
2. Materials and methods

2.1 Effluent and characteristics:

The dairy industry effluent used in this investigation was Pune Zilha Sahakari Dudh Utpadak Sangh Maryadit, Pune popularly known as Katraj Dairy, Pune from the manufacturing and processing unit located at Katraj location of city of Pune (India) and stocked in sealed plastic container at 277.15 K before the treatment to avoid degradation naturally. The characteristics of dairy industry effluent were: pH, 7.9–8.3; COD, 930-1250 mg/l; BOD_5, 650 - 670 mg/l; total suspended solids, 880 - 820 mg/l, temperature measured immediately after collecting the sample from the storage tank, 27-35ºC.

2.2 Experimental setup and procedure:

The experimental set up designed in this study / experimental work is shown in figure, principally consists of a cubical shaped reactor of 5 x 10^{-3} cubic meter to hold a sample of 2.5 x 10^{-3} cubic meter. Material of Construction of the reactor is acrylic (melting point: 433.15 K). Aluminum / Stainless Steel (SS 304) rods of 5 x 10^{-2} meter diameter and 20 x 10^{-2} meter length are used as electrodes for different sets of experiments. The length of electrodes dipped into the solution is approximately 10 x 10^{-2} meter. The anode and cathode are arranged vertically through the pores of the lid of the reactor and parallel to each other and then connected to an external direct current power source. The distance between the two electrodes varies experiment to experiment from 2.5 x 10^{-2} meter to 10 x 10^{-2} meter. The bottom of the cell is allowed for easy stirring by magnetic stirrer. The rotational speed of the magnetic needle of the stirrer varies from 50 to 200 rpm by the span of 50 rpm, according to the experiment conducted. Aforetime every run, the impurities on the surfaces of electrodes were eliminated by immersing them in the solution of Hydrochloric Acid (15% W/V) for 2 - 3 minutes and then cleansed with demineralised water (Ugurlu et al., 2007). At the termination of each experimental (i.e. after the process of electrocoagulation) run, the sample was transferred into separate beaker and it was kept uninterrupted for 1 hour in order to permit the flocs thus formed during electrocoagulation to settle down. After the settling time of 1 hour, the supernatant sample was collected to carry out the analysis of removal COD, BOD_5 and electrical energy consumption. The chemical oxygen demand and biochemical oxygen demand analysis were carried out by procedures described in standard methods. (Greenberg AE et al., 1995)



[Figure (1): Schematic Diagram of Reactor for the process of Electrocoagulation]

3. Results and discussion

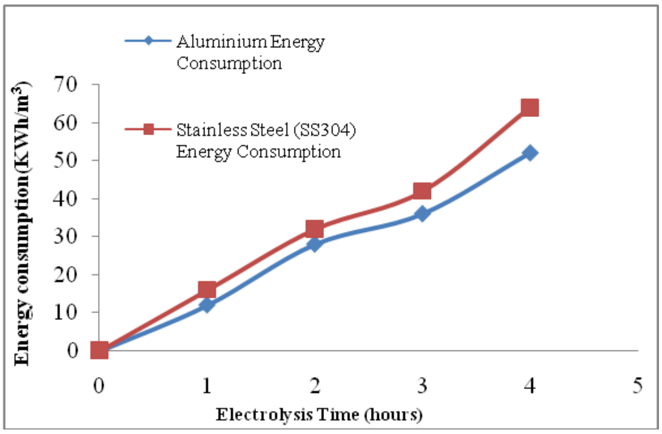
In the various batches, the effects of parameters such as change in the material of electrode, distance between the electrodes, electrolysis time, variation in the input of voltage, speed of rotation of the stirrer were investigated for percentage COD / BOD_5 removal and consumption of energy.

3.1 Effect of Electrode Material on energy consumption:

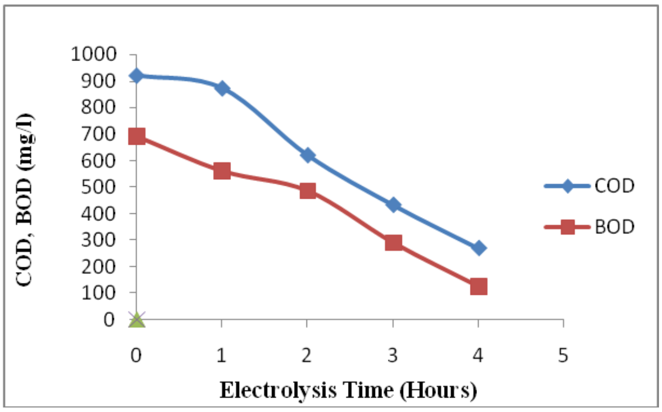
A series of experimentations was performed at the room temperature with initial pH of 7.9 for 4 hours. The Distance between the electrodes was maintained at 2.5 x 10^{-2} meter and voltage of 25 V was allowed to pass through the sample of effective volume 2 x 10^{-3} cubic meter. The rotational speed was maintained at 150 rpm. The sample showed 92% removal of COD and 89% removal of BOD_5 when Stainless Steel (SS 304) was used as the material of electrode and the sample with same initial characteristics showed 90% removal of COD and 86% removal of BOD_5 when aluminium (SS 304) was used as the material of electrode. Also, the consumption of aluminium electrode was quite noticeable. There was very less consumption of Stainless Steel (SS 304) electrode. The graph thus produced portrays the pattern of power consumption by Aluminium and Stainless Steel (SS 304) electrodes. It's clear from figure (2), that the consumption of electricity is more in Stainless Steel (SS 304) than it is in Aluminum.

3.2 Effect of electrolysis time on COD and BOD_5:

There was a gradual increase observed in the pH in the course of time while conducting a set of experiments starting from pH of 7.9. It was observed to become more alkaline. The distance between the electrodes was maintained at 2.5 x 10^{-2} meter and voltage of 25 V was allowed to pass through the sample of effective volume 2 x 10^{-3} cubic meter, maintaining the rotational speed at 150 rpm. The sample had initial COD of 920 mg/l and BOD_5 of 690 mg/l. The factors i.e., COD and BOD_5 show a piecemeal decrease. This is a desirable thing for the technique to be more efficient. This effect has been elaborated in the Figure (3).



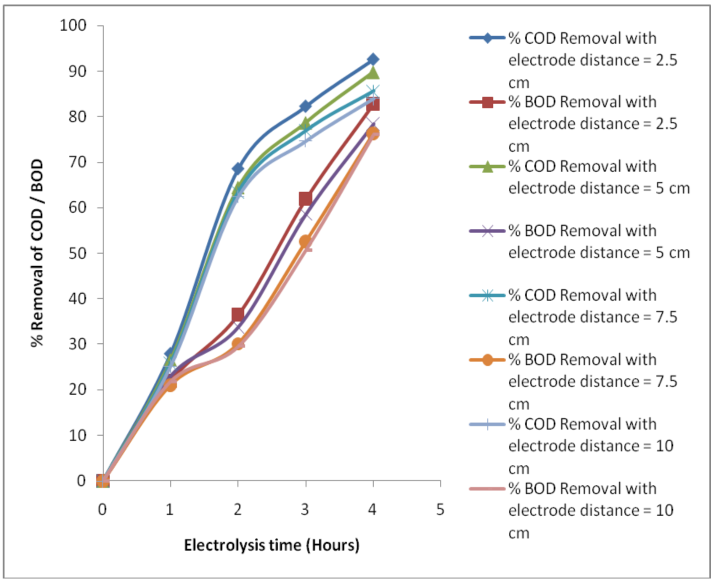
[Figure (2): Effect of Electrode Material on Energy Consumption]



[Figure (3): Effect of electrolysis time on COD /BOD_5 Removal]

3.3 Effect of electrode distance:

A set of experiments was performed at the room temperature with initial pH of 7.9. The rotational speed was maintained at 150 rpm. The electrolysis time was 4 hours and voltage of 25V was allowed to pass through the sample of effective volume 2 x 10^{-3} cubic meter. It is observed that the percentage of COD / BOD_5 removal increased with increasing electrode distance up to 7.5 cm beyond which there is not much increase in the percentage of COD and BOD_5 removal. This is due to the minimal interaction of ions with Polymers of hydroxide base. (Modirshahla et al., 2007). The best results were obtained at the electrode distance of 2.5 x 10^{-2} meter. Therefore, for the other sets of experiments the electrode distance of 2 x 10^{-2} meter was maintained to get the most efficient results at given parametric conditions. The figure (4) shows the pattern of percentage removal of COD / BOD_5 in accordance with the electrode distance.

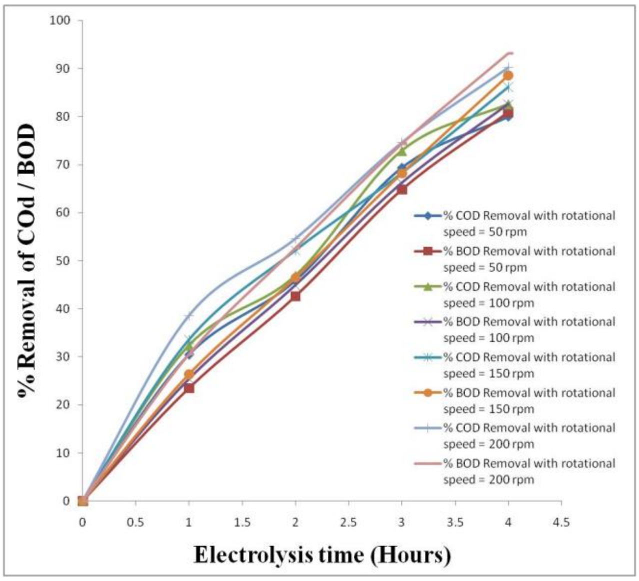


[Figure (4): Effect of electrode distance on Percentage COD / BOD_5 Removal]

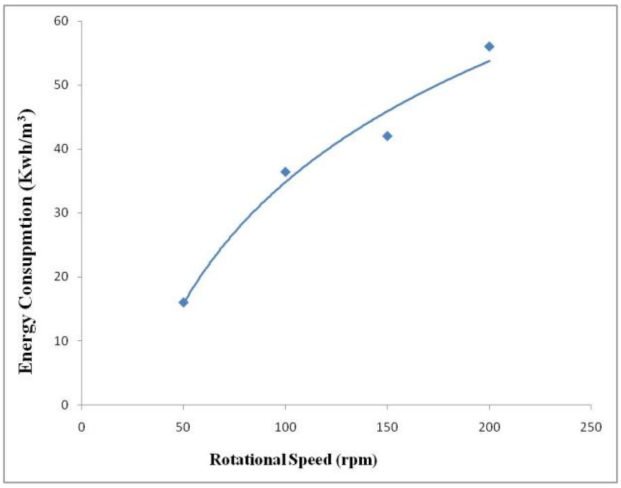
3.4 Effect of rotational speed:

Main objective of rotational speed is to disperse the coagulant matter formed at the electrode surface in the reactor efficiently, so that the content in it becomes homogenous. The percentage of COD / BOD_5 removal reaction is monitored by diffusion and the increment in rotational speed causes the increase in the vigor of turbulence, hence lowering the thickness of diffusion layer at the surface of electrode and by that enhancing the mixing conditions in the bulk of electrolyte (El-Ashtoukhy et al., 2009), (Serkan Bayar et al., 2011). Bouhezila et al (2011) too, noticed that the pollutant deterioration has an increment with increasing the rotational speed down to particular value beyond which there is hardly any noticeable reduction. A series of experimentation was performed at the room temperature with initial pH of 7.9 to confirm these findings. The electrolysis time was fixed to 4 hours and electricity of voltage of 25 V was allowed to pass through the sample of effective volume 2 x 10^{-3} cubic meter. Rotational speed was varied from 50 to 200 rpm with an increase of 50 rpm per run. It has been noted that the percentage of removal of COD, BOD_5 goes on increasing with the increasing rotational speed. The figure (5) shows the pattern of percentage removal of COD / BOD_5.

It is observed that the consumption of energy depreciated with increase in the rotational speed principally because it enhances the strength of turbulence and shortens the thickness diffusion layer at the surface of electrode. It can also be established that the energy consumption and operating cost are observed to have a significant decrease with the increase in rotational speed up to 150 rpm beyond which there no noticeable cutback of energy consumption. Following table shows values of energy consumption after completion of certain sets of experimentations with respect to rotational speed.



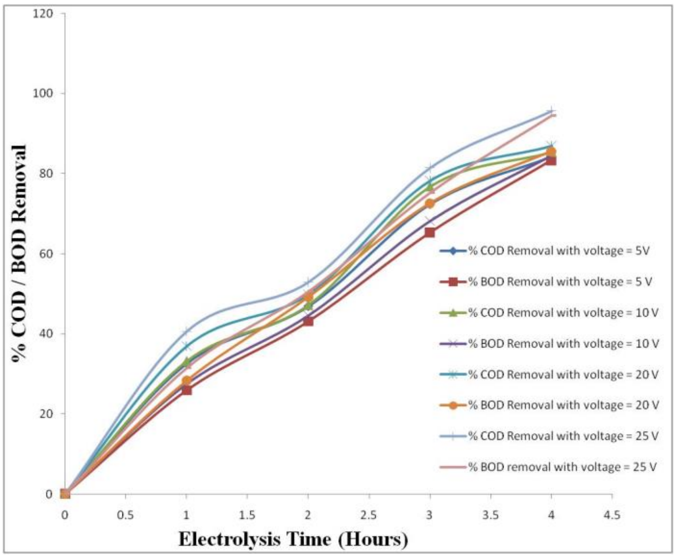
[Figure (5): Effect of rotational speed on Percentage COD / BOD_5 Removal]



[Figure (6): Effect of Rotational Speed on Energy Consumption]

3.5 Effect of variation of voltage:

It has been observed that with the increasing voltage, the parentage of COD / BOD_5 removal is increased. The increase in the voltage eventually causes the faster ionization and thereby agile is the process of electrolysis. A set of experiment was performed at the room temperature with initial pH of 8.1. The rotational speed was maintained at 150 rpm. The electrolysis time was at 4 hours and electricity of voltage of 25 V was allowed to pass through the sample of effective volume 2 x 10^{-3} cubic meter. The percentage of removal of COD and BOD_5 goes on increasing. The following tables show the values of percentage removal of COD / BOD_5. Sridevi V. et al. (2015) also got the similar pattern of increase in the values of percentage removal of COD / BOD_5 with the increase of voltage. Figure (7) elaborates the effect of variation of voltage on percentage removal of COD / BOD_5.



[Figure (7): Effect of variation of voltage on Energy Consumption]

4. Conclusions:

The present study is about the effect of various parameters suchlike change in the material of electrode, distance between the electrodes, electrolysis time, variation in the input of voltage / direct current, speed of rotation of the stirrer etc on the percentage removal of chemical oxygen demand and biochemical oxygen with respect to the operating conditions: speed of rotation at 150 rpm, distance between the Stainless Steel (SS 304) electrodes as 2 x 10^{-2} meter, pH of 7-8 and electrolysis time of 4 hours. Out of the electrodes used for the experimentations, Stainless Steel (SS 304) was identified as more prominent than aluminium electrode that shows a phenomenon of deterioration. Under these optimal specifications, the consumption of electricity was found to be increasing with respect to time and voltage. Also, increase in the voltage resulted in increase in the percentage removal of COD and BOD_5. With a series of batch mode experimentation to treat samples of effluent acquired from dairy industry, it can be concluded that the implementation of electrocoagulation technique is fairly economical and gives optimal results with clean and odorless output as compared with the other techniques involving various chemicals etc.

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