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Treatability studies of Dairy Wastewater by Electrocoagulation Process

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Abstract

Dairy industry wastewater is characterized by high biochemical oxygen demand (BOD5), chemical oxygen demand (COD) and other pollution load. The purpose of this study was to investigate the effects of the operating parameters, such as applied voltage, pH and reaction time on a real dairy wastewater in the electro coagulation process. For this purpose Stainless steel electrodes were used in the presence of Sodium chloride as electrolytes. This study gives us the result of BOD and COD removal from dairy wastewater through Electro coagulation Process using Stainless Steel as a electrode material

In the first stage, experimental studies were carried out using Stainless steel electrode combinations (SS-SS) with varying voltage (10v,20v and 30v) and constant dosage of 0.5gms of NaCl as an electrolyte by keeping the constant distance between electrodes. In the second stage, studies were carried out at different initial pH of 4,6,8 and 10 under the optimum contact time. The spacing between the electrode were maintained 1.5cm throughout the experiment

From the result we can conclude that Electro-coagulation with Stainless steel- Stainless steel electrodes is a safe, reliable, convenient and efficient route for removal of COD and BOD from Dairy waste water.When electrodes are placed with an efficient distance of 1.5 cm. Best removal efficiency was achieved in the pH 6.Efficient removal rate increased with optimum Voltage of 30V.

Keywords***: Dairy wastewater , Electrocoagulation process, BOD,COD***

Introduction

The dairy industry is generally considered to be the largest source of food processing wastewater in many countries. Water is used throughout all steps of the dairy industry, including cleaning, sanitization, heating, cooling, and floor washing; naturally the industry's need for water is huge . In general, wastes from the dairy processing industry contain a high concentration of organic material such as proteins, carbohydrates and lipids, high BOD_5 and COD, and high concentrations of suspended solids and suspended oil-grease. The BOD_5 concentrations for dairy factory wastewaters can vary widely depending on the season or product cycle. For instance, it has been reported that cheese factories have BOD_5 ranging from 588 to 5000 mg/1 whereas factories producing cream have BOD5 in the range of 1200–4000 mg/L.

Dairy wastewaters are generally treated usually using biological methods such as activated sludge process, aerated lagoons, aerobic bioreactor, trickling filters, sequencing batch reactor (SBR), anaerobic sludge blanket (UASB) reactor, anaerobic filters, biocoagulation, etc.. Aerobic biological processes are high energy intensive whereas, anaerobic treatment of dairy wastewater reflects very poor nutrient removal and effluents treated by anaerobic biological processes need additional treatment . On the other hand, the physical/chemical methods that have been proven to be successful are coagulation/flocculation

1.1 Electrocoagulation Process

In the recent years, investigations have been focused on the treatment of wastewaters using electrocoagulation (EC) because of the increase in environmental restrictions on effluent wastewater. Electrocoagulation (EC) is an electrochemical method for treating polluted water which has been successfully applied for treatment of soluble or colloidal pollutants, such as slaughterhouse wastewater , vegetable oil refinery , dairy industry wastewater, slaughterhouse wastewater, nitrate bearing wastewater , wastewaters containing heavy metals, pesticides and phenolic compounds, etc., but also drinking water for fluoride and humic acid removal.

In electrocoagulation treatment, the destruction of organic compounds is achieved by short-lived species (OH, O, and O3), generated at the anode. It has been proposed that dye molecule degradation by electro chemical oxidation occurs in 2 steps. In the first stage,anodic electrolysis of water results in formation hydroxyl radical that are adsorbed onto the active site of the electrode. In the second stage, the dye molecules are oxidized by hydroxyl radicals, which are continually being formed at the anode.

1.2 A Brief Description of Electrocoagulation Mechanism:

A simple electrocoagulating reactor is made up of one anode and one cathode. When a potential is applied from an external power source, the anode material undergoes oxidation, while the cathode will be subjected to reduction or reductive deposition of elemental metals . If iron or aluminum electrodes are used, the generated$Fe^{3+}_{(aq)}$ or $Al^{3+}_{(aq)}$ ions will immediately undergo further spontaneous reactions to produce corresponding hydroxides and/or polyhydroxides.The Fe(II) ions are the common ions generated the dissolution of iron. In contrast, OH^{-}ions are produced at the cathode. By mixing the solution, hydroxide species are produced which cause the removal of matrices (dyes and cations) by adsorption and coprecipitation. In the study of iron anodes, two mechanisms for the production of the metal hydroxides have been proposed.

MECHANISM 1

Anode:

$4Fe_{(s)} \rightarrow 4Fe^{2+}_{(aq)} + 8e^{-}$ -----(1)

$4Fe^{2+}_{(aq)} + 10H_2O_{(l)} + O_{2(aq)} \rightarrow 4Fe(OH)_{3(s)} + 8H^{+}_{(aq}$ ----------(2)

Cathode:

$8H^{+}_{(aq)} + 8e^{-} \rightarrow 4H_{2(g)}$ -----(3)

Overall:

$4Fe_{(s)} + 10H_2O_{(l)} + O_{2(aq)} \rightarrow 4Fe(OH)_{3(s)} + 4H_{2(g)}$ -----(4)

MECHANISM 2

Anode:

$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^{-}$ -----(5)

$Fe^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Fe(OH)_{2(s)}$ -----(6)

Cathode:

$2H_2O_{(l)} + 2e^{-} \rightarrow H_{2(g)} + 2OH^{-}_{(aq)}$ -----(7)

Overall:

$Fe_{(s)} + 2H_2O_{(l)} \rightarrow Fe(OH)_{2(s)} + H_{2(g)}$ -----(8)

Oxidation

$2Cl^{-} \rightarrow Cl_2 + 2e^{-}$ -----(9)

$Cl_{2(g)} + H_2O \rightarrow HOCl + H^{+} + Cl^{-}$ -----(10)

$Fe(OH)_2 + HOCl \rightarrow Fe(OH)_{3(s)} + Cl^{-}$ -----(11)

$Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ -----(12)

$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^{+}$ -----(13)

2.Materials And Methods:

2.1 sequence of investigation:

Following are the sequence with which the entire investigations were carried out:

- Setting of electro-coagulation reactor (mono polar).
- Experimental studies for different operating conditions for COD and BOD removal using Stainless steel as the electrode material
- Experimental study for dairy Industrial Effluent .

2.2. setting of electro-coagulation reactor (monopolar) :

The studies were exercised in a lab-scale batch system, which was composed of an borosil glass beaker of 1000ml capacity. The Electrochemical cell consists of an undivided reactor where both anode and cathode were placed vertical and parallel to each other. Regulated DC dual power supply (EL POWER 0 – 30 Volts and 0 – 5A) was used as a power source to supply and maintain current /voltage across the electrodes. The electrodes were operated in mono-polar mode by connecting electrodes to the power supply. The electrical contact was established with the help of copper wire and crocodile clips. The system was equipped with magnetic stirrer with hot plate (REMI Magnetic stirrer) in order to keep the electrolyte well mixed.

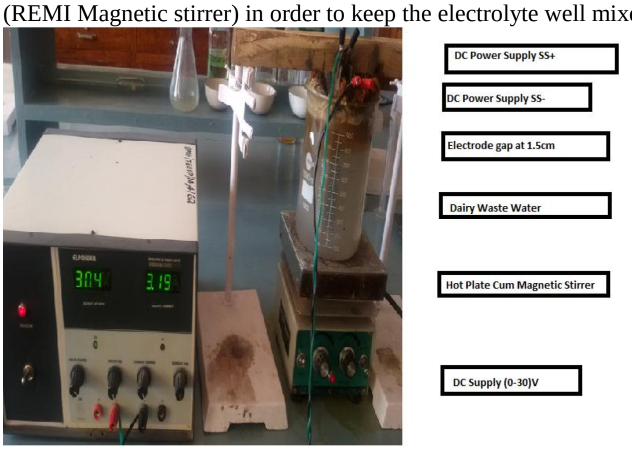

Fig:1 The schematic diagram of the experimental setup

2.3 Experimental studies for different operating conditions using Stainless Steel as electrode material (SS):

The EC process was performed with a monopolar mode for Stainless Steel-Stainless Steel, combinations. The electrolysis was carried out at different Voltages such as 10V, 20V and 30V under galvanostatic conditions for all combination of Stainless steel solid electrodes. The batch experiments were conducted for spacing between the electrodes of 1.5 cm. The samples were drawn at regular intervals of 30 min time and tested for COD and BOD as per standard methods. To remove the oxide/or passivation layer from the electrodes, the electrode surfaces were grinded with sand paper and washed before each experiment. Meanwhile, the collected samples were kept for settling and the volume of sludge generated is also recorded.

Operating Parameters Considered for the present study:

- Applied Voltage/current
- Contact Time
- Ph

Fig:2 Stainless Steel electrode before EC

3.RESULTS:

3.1 Treatment of Actual Wastewater:

The applicability of the electro coagulation process for actual waste water was validated by treating an dairy industrial effluent. Stainless steel – Stainless steel combinations of electrode(SS-SS) was used for the removal of COD and BOD. Table: shows the results of main characterics of industrial wastewater sample.

Table1: Characteristics of the dairy wastewater before EC treatment:

SI.No	PARAMETER	CONCENTRATION
1	pH	6.8
2	COD mg/lt	1376
3	BOD mg/lt	904
4	COD/BOD_5	1.52

3.2 Electric energy consumption:

Electrical energy consumption and current efficiency are very important economical
parameters in the electrocoagulation process. Electrical energy consumption was calculated using the equation [27]

$E = u\,I\,t$ --------1

Where E = electrical energy (Wh), u = cell voltage (volt), I = current in ampere (A) and t =
time of electrocoagulation process (hour). electrolysis time. The current efficiency (C.E.) of the electrocoagulation process was calculated by the following equation [16].

$C.E. = [(\Delta m_{exp})/(\Delta m_{theo})]X100$ ---------2

This calculation was based on the comparison of experimental weight loss of iron electrodes (Δmexp) during electrocoagulation process with theoretical amount of iron dissolution (Δmtheo) according to the Faraday's Law

$\Delta m_{theo} = (M/t)/nxF$

Where M is the molar mass of iron, (g.mole-1), t is the applied electrolysis time (second), I is the current in ampere (A), n is the number of electron moles and F is the Faraday constant (F = 95487 C mole-1). As Fe (OH)2 (s) is supposed to be the formed species, the number of electron moles in dissolution reaction is equal to 2.

Table2: Electrical energy during electrocoagulation process:

	Applied Voltage		
	10V	20V	30V
Energy Consumption (Kwh/L) SS-SS Electrode (1.5mm Thickness)	0.080	0.089	0.095

Table3: Weight of the Electrode before and after the EC:

Electrode	Before treatment	After treatment	
		Anode	Cathode
Stainless Steel	43.57 gms	38.9 gms	44.8 gms

3.3 Effect of Applied Voltage and Contact Time:

Table4: Results for Effect of Applied Voltage and Contact Time on COD Removal for SS-SS electrodes (1.5mm thickness):

Time in min	10 Volts		20 Volts		30 Volts	
	COD mg/lt	% COD	COD mg/lt	% COD	COD	% COD
30	600	54	400	69	152	88
60	496	62	328	75	80	94
90	424	68	264	80	72	94
120	368	72	216	84	80	94
150	336	74	168	87		
180	312	76	104	92		

Table5: Results for Effect of Applied Voltage and Contact Time on BOD Removal for SS-SS electrodes(1.5mm thickness):

Time in min	10 Volts		20 Volts		30 Volts	
	BOD mg/lt	% BOD	BOD,mg/lt	% BOD	BOD , mg/lt	% BOD
30	405	48	245	69	105	87
60	335	57	220	72	70	91
90	315	60	180	77	70	91
120	250	68	145	82	70	91
150	240	69	115	85		
180	210	73	75	90		

Table6: Results for Effect of Applied Voltage and Contact Time on COD/ BOD_5 Removal for SS-SS electrodes(1.5mm thickness):

Time in min	10 Volts	20 Volts	30 Volts
	COD/BOD_5 Removal	COD/BOD_5 Removal	COD/BOD_5 Removal
30	1.48	1.63	1.44
60	1.48	1.49	1.14
90	1.34	1.46	1.14
120	1.47	1.48	1.14
150	1.4	1.46	
180	1.48	1.38	

3.4 Effect of pH:

In case of SS – SS Electrode combination the maximum COD and BOD removal efficiency of 94% and 92% was recorded at initial pH as 6 for the voltage of 30V for the time interval of 60min . The removal efficiency showed the decreasing trend with increase in initial pH. In case of initial pH 6 the pH of the treated sample has attained the acceptable range as per the disposal standards.

Initial pH of the dairy industrial waste water before the treatment is 6.8.

Below graph shows the removal of COD and BOD foe the different pH. The maximum removal is achieved at the pH of 6.

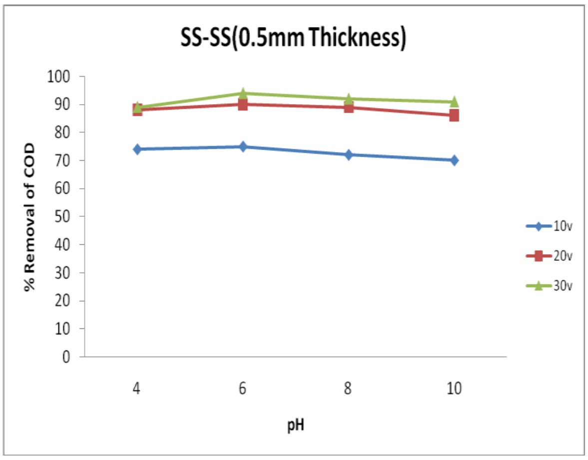

Fig:3 Effect of pH on COD removal using SS – SS Electrodes at varying Voltage.

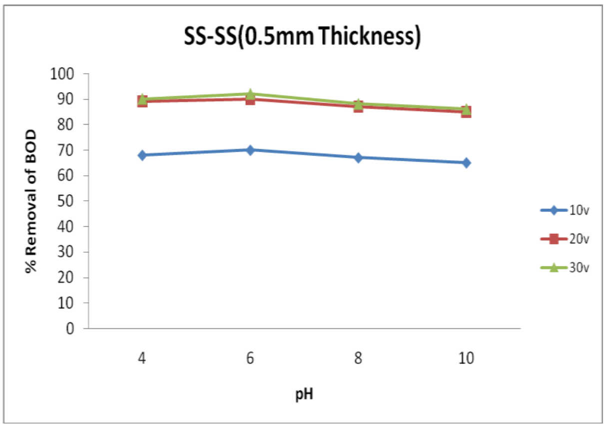

Fig:4 Effect of pH on BOD removal using SS – SS Electrodes at varying Voltage.

3.5 Wastewater And Sludge Characterics After Electrocoagulation :

The wastewater and sludge produced during the electrocoagulation treatment was tested for the presence of heavy metals. when stainless steel is used as an electrode during electrocoagulation process. Table 7 and 8 shows the chemical composition of stainless steel for both waste waster and sludge

Table7:Results of Wastewater produced during EC when Stainless steel used as an electrode

SI.No	PARAMETERS	TEST METHOD	PROTOCOL	UNIT	RESULT
1.	Total Chromium	3111C	APHA, 22nd Edition	Mg/lt	3.24
2.	Manganese as Mn	3111B		Mg/lt	49.62
3.	Nickel as Ni	3111B		Mg/lt	3.01

Table8: Results of Sludge produced during EC when Stainless steel used as an electrode.

SI.No	PARAMETERS	PROTOCOL	UNIT	RESULT
1.	Total Chromium	Soil Chemical Analysis by M L Jackson	Mg/lt	299.77
2.	Manganese as Mn		Mg/lt	49.98
3.	Nickel as Ni		Mg/lt	12.52

4. Conclusion:

1. Electro-coagulation with Stainless steel- Stainless steel electrodes is a safe, reliable, convenient and efficient route for removal of COD and BOD from Dairy waste water.
2. When electrodes are placed with an efficient distance of 1.5 cm. Best removal efficiency was achieved in the pH 6.
3. Efficient removal rate increased with optimum Voltage of 30V.
4. The Optimum removal of COD and BOD was achieved during 30 volts for the time duration of 60 min
5. COD(95%) and BOD(92%) removal was achieved when Stainless steel- Stainless Steel is used as an electrode.

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