# Treatment of Dairy Wastewater by Electrocoagulation Method

Arshida A S, Muhammad Fayis T

**Abstract**— Dairy industry is a large-scale food production and dairy processing require large volumes of water for their operations and therefore generate a considerable amount of waste effluents. Dairy wastewater has been a major environmental concern because of massive effluents characterized by high pollution load. It is enriched in fat, lactose, nutrients, detergents and sanitizing agents & also contains biodegradable carbohydrates and is characterized by the high BOD and COD, organic and inorganic matters and dissolved/suspended solids. Generally dairy wastewaters are treated using aerobic or anaerobic biological methods like activated sludge process, sequencing batch reactor (SBR), anaerobic sludge blanket (UASB) reactor, anaerobic filters. Aerobic biological processes are energy intensive, whereas anaerobic methods are poor in nutrient removal.Electrochemical (EC) treatment method is a feasible technique for wastewater treatment, including dairy wastewater .Electro coagulation has several advantages of simple equipment, ease of operation, less treatment time, reduction of chemicals addition providing rapid sedimentation of flocs, less amount of sludge production .This study is done to investigate the feasibility and suitability of electro coagulation technology for dairy wastewater treatment ,to compare the efficiency in removing pollutants in dairy waste water by electro coagulation method by using different electrodes, electrode orientation , voltages ,speeds in which the cell rotated,arrangements of cell, current density and to combine the most efficient parameters of the electro coagulation cell for the cost effective treatment of the dairy waste water with maximum efficiency

**Keywords**—Cell design, Coagulation, Dairyeffluent, Electrodes, Electrocoagulation, Industrial waste water, Oxidation, Removal efficiency

————————————— ◆ —————————————

## 1 Introduction

Industrial wastewater is now one of the major sources of environmental pollution. Apart from the organic carbon, wastewater also contains significant amounts of organic/inorganic nutrients like nitrogen, protein, ammonia, nitrite and phosphate including biorefractory organic compounds which resist conventional treatment techniques[3].

Dairyeffluents are concentrated in nature. Main contributions to these are carbohydrates, proteins and fats. In dairy industry, rawmil is processed into different products such as consumer milk, condensedmilk, driedmilk(milk powder),cheese,butter,youghurt,ice cream etc.Water is used throughout all steps of dairy industry[5]. Various technologies for the treatment of dairy wastewater are membrane filteration,coagulation,biological treatment and adsorption.Biological methods are very costly in terms of operating as well as fixed cost[1].On the other hand, the physical and chemical have been reported to generate huge volume of secondary pollutants,and are costly due to expensive adsorbents, coagulants and chemical usage[4].Regarding the priority of environmental issues, it is necessary to adopt a positive approach to sustainable management of water, soil and other finite resources and monitor industrial wastewater including dairy wastewater containing organic and inorganic copounds[2]. Among the different electrochemical methods, the most applied technologies include the oxidation using different electrodes, cathodic removal of metals and electrocoagulation[3].

Waste water from the dairy industry is usually generated in an intermittent way, so the flow rates of these effluents change significantly. High seasonal variations are also encountered frequently and correlate with the volume of milk received for processing which is typically high in summer and low in winter month.The characteristics of the effluents also vary greatly depending on the type of system and the method of operation used. The volume of waste water generated by the activity can vary from one to five times the volume of processed milk, depending on the final product and the technological level of the dairy industry[7]. In the treatment of dairy industry effluents, biological treatments such as activated sludge, aerated ponds, biological filters, up flow anaerobic sludge blanket (UASB) reactor, anaerobic filter, etc., are used. Aerobic biological processes have high energy consumption, and effluents treated by anaerobic biological processes often require additional treatment. Regarding the physicochemical processes, the most cost-effective ones are coagulation– flocculation The treatment of liquid effluents by electrocoagulation (EC) is considered an advanced type of treatment, that presents high efficiency and compact reactors that are easy to control and operate[8].

## 2 The Dairy Industry

### 2.1 General Background

The milk is one of the most important commodity entering trades and it is required in everyday life as an article of food. Since the milk is highly perishable, basic public health and economic consideration is required that consumer should be provided with the product which is of good quality, pure, free from pathogenic bacteria[5]. To maintain quality standard, quality control operation has to be performed at all the stages of production of milk which includes maintenances of sanitary conditions at milking place, storage, transportation and handling the milk at reception docks, processing and packing etc till the milk is delivered to consumer[8].

## 2.2 Dairy Technology

Milk Process Technique or milk treatment is the preparation of raw milk including heat treatment as a precondition for milk processing. The milk processing is the quality oriented activity of manufacturing, packing of dairy based products on the basis of treated milk [9].

A chain of operations involving receiving and storing of raw materials, processing of raw materials into finished products, packaging and storing of finished products, and a group of other ancillary operations are performed in the dairy industries [3].Clarification and separation generally, are accomplished by specially designed large centrifuges. Drying, condensing, etc. are also used in dairy industries for the production of various products.The details of operations involved are as given below,

- Milk Receiving Station: The milk cans are unloaded at the receiving station and emptied into a receiving tank, after testing for fitness and freshness.
- Pasteurization: Pasteurization is accomplished by heating either to 620C for 30 min. of at 710C for 15 seconds, followed by chilling to 40C. The milk is then bottled for distribution.
- Cheese Making: Cheese is made from milk in which fat to protein ratio is adjusted when the proper degree of settling of curd has been reached, it is cut into pieces and after further adjustment to temperature, is then allowed to settle.
- Butter, Butter Milk and Skim Milk: Milk is first passed through centrifugal machines to separate cream and skim milk. Cream is then churned until butter separates from the liquid and butter milk is left over. Ghee is prepared from the butter, sour milk is separated to remove fat and skim milk thus obtained is fed into large vats and treated with the acid to precipitate casein which is washed and dehydrated.
- Products of milk-raw milk storage:The total volume of storage silos can be very different and can vary from 20 to 100% of the dairy reception volume, usually storage vessels are installed individually on the outside of the buildings, are made of stainless steel or fibre glass and may have a volume of 20,000 to 2,00,000 L. A majority of wastewater gets produced during cleaning operations, especially between products changes when different types of products are produced in a specific production unit and clean-up operations [3].

## 3ELECROCOAGULATION

### 3.1 Theory of Electrocoagulation

Electro Coagulation is the process of applying a direct current voltage to the waste water to be treated using submerged electrodes which act as the anode and cathode made of metal plates, both submerged in the solution being treated.. The current passes between the electrodes due to the conductivity of the water It is based on separation of the electrode material used as an anode. This also called "sacrificial anode" creates metals ions which act as coagulant agents [6].

The elctrocoagulation technique has been successfully used for the treatment of various wastewaters such as domestic wastewater , cyanide containing wastewater , tannery wastewater, textile wastewater, slaughter-house wastewater etc[11].

The electrical current acts on the suspended particles in the water, neutralising their charges and allowing the very fine solids to precipitate and settle. The electrical current also makes the electrodes sacrificial and in doing so, they give up their metal ions into solution in water. These ions act as chemical coagulants. Suspensions and emulsions are destabilised, solids coagulate and separate out and and hydrocarbons coalesce.EC produces significantly less sludge with much lower sludge handling costs. EC produces a broadly neutral pH, easy to dewater and non-leaching, oxide sludge. Handling and disposal costs are much reduced[5].

The EC occurs in three steps. In first step, coagulant is formed because of oxidation of anode. In second step, pollutants get destabilized and in last step the destabilized matters get united and then removedAs water passes through the electrocoagulation cell, multiple reactions take place simultaneously. First, a metal ion is driven into the water. On the surface of the cathode, water is hydrolyzed into hydrogen gas and hydroxyl groups. Meanwhile, electrons flow freely to destabilize surface charges on suspended solids and emulsified oils. As the reaction continues, large flocs form that entrain suspended solids, heavy metals, emulsified oils and other contaminants[9]. Finally, the flocs are removed from the water in downstream solids by separation and filtration process steps as shown in fig 1.

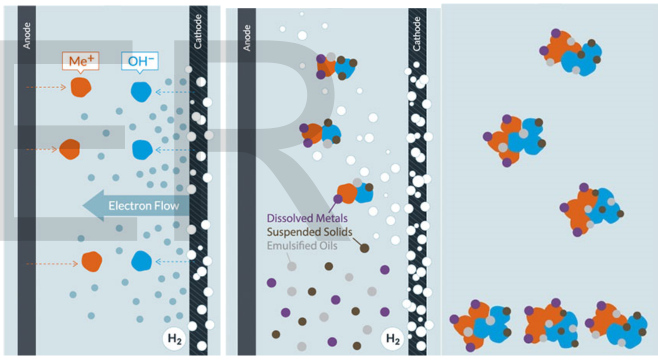


**Fig. 1** Processes in electrocoagulation (dissolution, coagulation, flocculation)

In this process in which the anode material undergoes oxidation with formation of various monomeric and polymeric metal hydrolyzed ionic species These metal ions and hydroxides remove organics from wastewater by sweep coagulation and/or by agglomeration with the colloidal particles present in the wastewater to form bigger size flocs which are ultimately removed by settling During EC, coagulants are obtained in situ by the dissolution of the anode. In this process if M is considered as anode, the following reactions will occur :

At the anode: $M(S) \rightarrow Mn+ (aq) + ne-$ (1)

$2H_2O (l) \rightarrow 4H+ (aq) + O_2 (g) + 4e-$ (2)

At the cathode $M n+ (aq) + ne- \rightarrow M(S)$ (3)

$2H_2O (l) + 2e- \rightarrow H_2 (g) + 2OH-$ (4)

$M n+ + nOH \rightarrow M (OH)n$ (5)

Freshly formed amorphous $M(OH)_3$ has large surface areas that are beneficial for rapid adsorption of soluble organic compounds and trapping of colloidal particles. As seen in the above reactions EC is a combination of oxidation, flocculation and flotation[8].

The key chemical reactions which occur at the anode and cathode when using Al and Fe electrodes are represented that a higher electrical current density is necessary for aluminium electrodes when compared to iron electrodes in the treatment of dairy wastewater by electrocoagulation. This is because of the greater oxidation potential of aluminium[7].

## 4 Materials and Methods

### 4.1 Sample Collection

Raw wastewater from a regional dairy industry Kozhikode milma located at peringolam, kunnamangalamcalicut was used. The effluent entering the effluent treatment plant collected just before entering was collected. This water is collected as the wash waters from the different sectors of the unit. The collected sample from this site and was then tested for quality analysis and electrocoagulation is also done . Any excess sample was preserved at 4 °C. The dairy wastewater was characterized for COD, BOD (5-day BOD), total solids ,Turbidity , temperature, pH , conductivity , alkalinity, acidity etc after collection and two more times during the study.The composite sample was homogenized for testing and characterization.Various reagents can be used for the homogenisation of the collected sample. Analytical reagent grade chemicals were used for analysis of wastewater samples before and after the treatment.

### 4.2 Experimental Setu

A batch EC reactor is designed and fabricated for the treatment of dairy effluents. The reactor is made up of borosil with a total working volume of 2 L. A beaker of diameter 13cm and height 18cm is used as the electrocoagulation reactor. Different electrodes made up of stainless steel, steel wool and graphite are used as an anode as well as cathode for the set up .

Mild steel electrodes of dimensions 10cm x 3cm are used.Between two electrodes rubber or a wooden log is placed for preventing it from short circuit. The space between the electrodes kept 1cm,3cm and 5cm.Refer fig 2

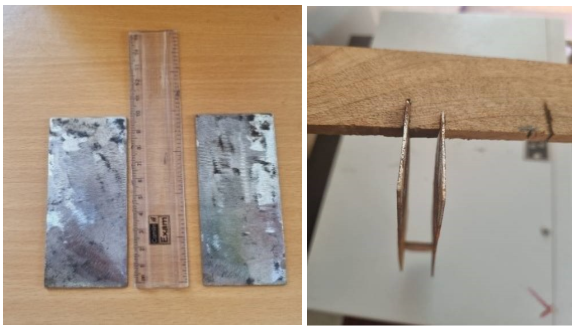

**Fig. 2** MS electrode and its orientation

Steel wool electrode of length 13 cm and 3 cm width is cut and used. Spacing between electrodes are kept varying as 3 cm and 5 cm. Refer fig 3

**Fig. 3** Steel wool electrode and its orientation

The orientation of all the electrodes were kept as monopolar. All the electrodes were kept at a depth of 7cm.
The electrodes are connecting to the DC power source using alligator clips as connecting wires. Refer fig 4

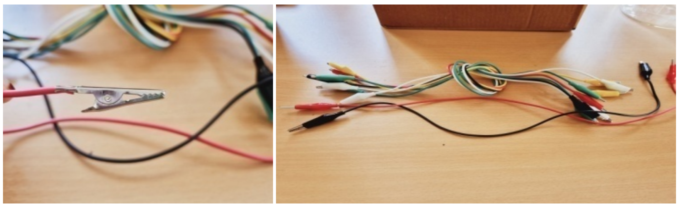

**Fig. 4** Aligator clip

The other end of connecting wire is connected to regular DC supply for completing the circuit. A DC power supply f 0-30 V and 0-5 Ampere is used as power supply .Refer fig 5.

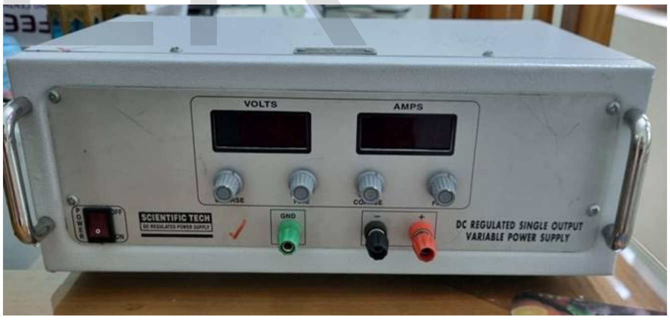


**Fig. 5** DC power source

In each run the voltage was varied to a desired value of 10, 15, 20, 24 and 30V. Each run of the experiment is kept for 30 minutes to two hours.

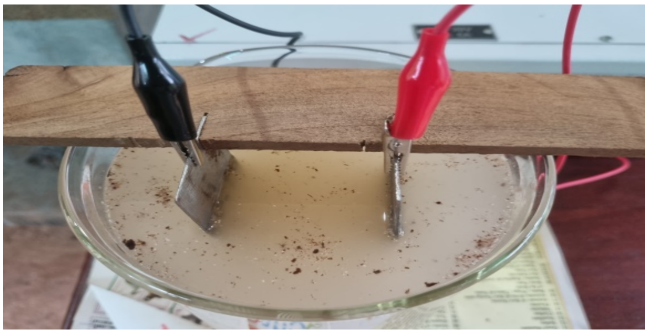

**Fig. 6** Experimental setup using MS electrode

The solution is mixed to form homogeneous solution . The pH is kept varying from 5 to 7 .NaCl is used in a concentration 2 grams per litre as a reagent for homogenising the sample.NaCl reagent is mixed with sample inorder to get homogeneous solution. The whole experiment was conducted by keeping the temperature between 20+-2$^{oc}$. The samples were obtained after the sample filtered after complete coagulation and quality analysis was done. The parameters measured were COD, BOD (5-day BOD), total solids ,Turbidity , temperature, pH , conductivity , alkalinity, acidity etc. Refer fig 6 for experimental setup.

## 6 RESULTS AND DISCUSSION

After collecting sample from the plant before it enters the effluent treatment plant , immediately it is tested and found out the concentration of chemical characteristics like Ph, COD,BOD,TDS,TSS,turbidity,coliform etc. It is found that coliforms were absent in the tested sample but has a good concentration of oxygen demand,turbidy ,dissolved solids etc.The sample was very acidic initially.It was turbid and milky in appearance and has a very pungent odour. Table 1 shows the values of concentration of various parameters tested initially.

TABLE 1
TESTED PARAMETERS OF DAIRY EFFLUENT BEFORE ENTERING TREATMENT PLANT

| Sl no | Parameters | Initial concentration |
|---|---|---|
| 1 | pH | 4.45 |
| 2 | COD(mg/l) | 4640 |
| 3 | BOD(mg/l) | 2500 |
| 4 | TDS(mg/l) | 2170 |
| 5 | TSS(mg/l) | 104 |
| 6 | Turbidity(NTU) | 147 |
| 7 | Total coliforms | Absent |
| 8 | Fecal coliforms | Absent |
| 9 | Electrical conductivity | 3330 |

The fresh sample is first electrocoagulated with mild steel electrodes at 1,3 and 5cm spacing between the two electrodes. The test is first conducted at a voltage of 5. Then the voltage is increased to 10,15,20,25, and 30. Time taken by the experiment to coagulate the testing sample completely is noted for each of the voltages tested. At 30 volts the sample coagulated within a hour, at 25 voltsit took 70 minutes, at 20 volts it took 95 minutes, at 15volts it took 100,at 10 volts took exactly two hours and at 5 volts it took more than 2 hours. After completing experiment the treated sample is tested for all the parameters tested before for initial concentration.Almost all the chemical parameters has shown a ambient decrease after treatment and the sample has become more basic after electrocoagulation with ms electrodes. The values of concentrations after treatment with ms electrodes are given below in table 2

TABLE 2
TESTED PARAMETERS OF DAIRY EFFLUENT AFTER ELECTROCOAGULATION WITH MS ELECTRODES

| Sl no | Parameters | Concentration |
|---|---|---|
| 1 | Ph | 6 |
| 2 | COD(mg/l) | 3450 |
| 3 | BOD(mg/l) | 1800 |
| 4 | TDS(mg/l) | 1878 |
| 5 | TSS(mg/l) | 98 |
| 6 | Turbidity(NTU) | 120 |
| 7 | Total coliforms | Absent |
| 8 | Fecal coliforms | Absent |
| 9 | Electrical conductivity | 3369 |

When the effluent is tested, COD has shown more difference from initial concentration, however all the parameters has shown some decrease anyway.

The second electrode was steel wool. It is a fabric type of strings made up of steel. Since it is a fibrous material, if it is kept at a distance of 1cm it will touch each other and there are high chances of short circuit. Thus it is tested by keeping at a distance of 3 as well as 5cm spacing. As in the case of ms electrodes, steel wool electrodes has also tested for all the voltages varying and the time for complete electrocoagulation is noted.At 30 volts the sample coagulated with 45 hours, at 25 volts it took an hours, at 20 volts it took 100 minutes, at 15volts it took 130,at 10 volts took almost two hour and at 5 volts it took exactly 2 hours. As compared with ms electrodes time taken for complete coagulation has shown an increase from 5 to 20 voltages. Later for 25 and 30 volts, the time required for complete coagulation has decreased as compared as in the case of ms electrodes.

TABLE 3
TESTED PARAMETERS OF DAIRY EFFLUENT AFTER ELECTROCOAGULATION WITH STEEL WOOL ELECTRODES

| Sl no | Parameters | Result |
|---|---|---|
| 1 | Ph | 6.5 |
| 2 | COD(mg/l) | 3200 |
| 3 | BOD(mg/l) | 1560 |
| 4 | TDS(mg/l) | 1280 |
| 5 | TSS(mg/l) | 96 |
| 6 | Turbidity(NTU) | 96 |
| 7 | Total coliforms | Absent |
| 8 | Fecal coliforms | Absent |
| 9 | Electrical conductivity | 3328 |

After treating with steelwool electrodes, the sample is tested for chemical parameters. The sample has shown a tremendous decrease from initial concentrations. When compared with concentrations of ms electrodes, steel wool has shown further decrease for the values of the tested parameters.

The third and final electrodes was of graphite rods. It was treated by keeping at a distance 3 and 5cm.Volatge is kept varying from 5 to 30 volt with an increase of 5 volt in each step as in the previous cases. The time for complete electrocoagulation is also noted. The time has showna big difference in all the voltages when compared with ms electrodes and some increase when compared with steel wool electrodes.It took about 200 minutes for coagulation with 5 volts and 185,150,120,110,and 100 minutes for 10,15,20,25,and 30 volts respectively.

As in both the above cases, sample coagulated with graphite electrodes are also tested for its chemical properties. All the properties tested earlier in both the cases were tested for graphite electrodes also.Table 4 shows the values for the tested parameters.Values when compared with initial concentrations has shown decrease.But when compared with ms and steel wool electrodes, the parameters have increased a little bit .

TABLE 4
TESTED PARAMETERS OF DAIRY EFFLUENT AFTER ELECTROCOAGULATION WITH GRAPHITE ELECTRODES

| Sl no | Parameters | Result |
|---|---|---|
| 1 | Ph | 7 |
| 2 | COD(mg/l) | 3902 |
| 3 | BOD(mg/l) | 2000 |
| 4 | TDS(mg/l) | 1980 |
| 5 | TSS(mg/l) | 100 |
| 6 | Turbidity(NTU) | 140 |
| 7 | Total coliforms | Absent |
| 8 | Fecal coliforms | Absent |
| 9 | Electrical conductivity | 3345 |

When different electrodes were used with varying voltages, time require was noted and plotted as a graph. It is shown in fig 7.

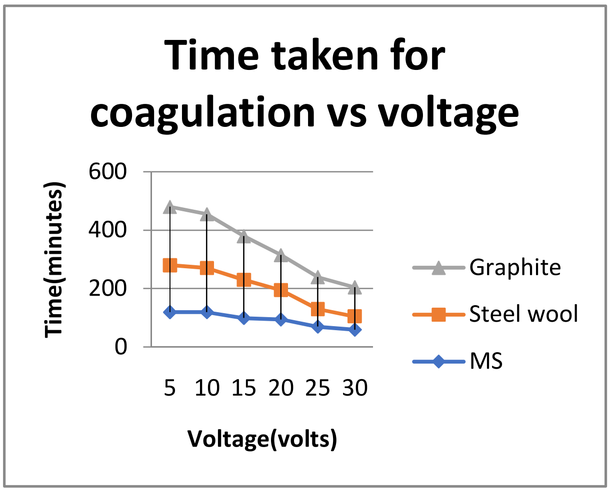


**Fig. 7** Time taken by each electrode to coagulate the effluent in different voltage

The BOD removal efficiency of different electrodes are shown in fig 8. BOD is removed maximum when steel wool is used as electrode . MS has has also shown optimum removal when compared with graphite electrodes.

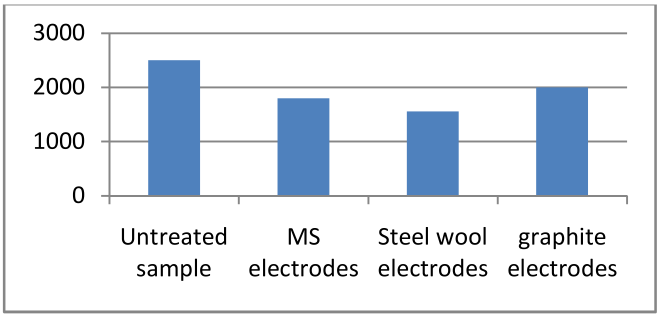


**Fig. 8** Removal efficiency of BOD with different electrodes

The COD removal efficiency of different electrodes are shown infig 9. As in the case of BOD, here also steel wool have shown better removal efficiency.

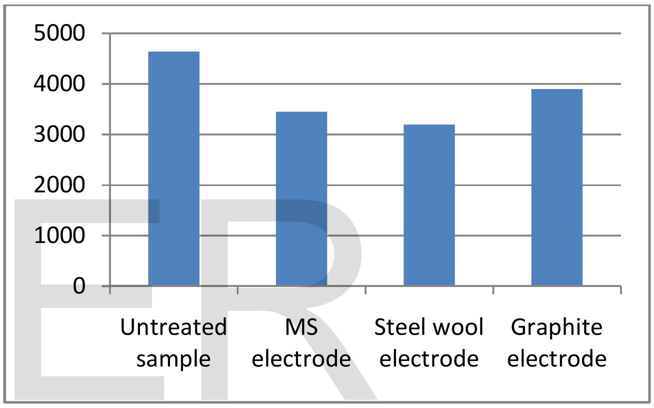


**Fig. 9** Removal efficiency of COD with different electrodes

The TSS removal efficiency of different electrodes are shown in fig 10. As in the above cases , here also steel wool have shown better removal efficiency, then MS and then graphite.

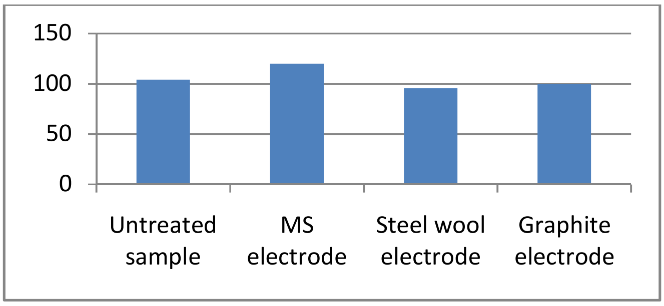


**Fig. 10** Removal efficiency of TSS with different electrodes

The TDS removal efficiency of different electrodes are shown in fig 11. As in the above cases , here also steel wool have shown better removal efficiency, then MS and graphite has shown least removal efficiency.

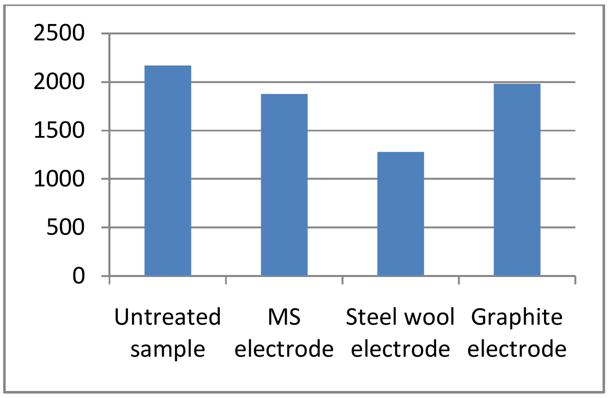


**Fig. 11** Removal efficiency of TDS with different electrodes

The turbidity removal efficiency of different electrodes are shown in fig 12.

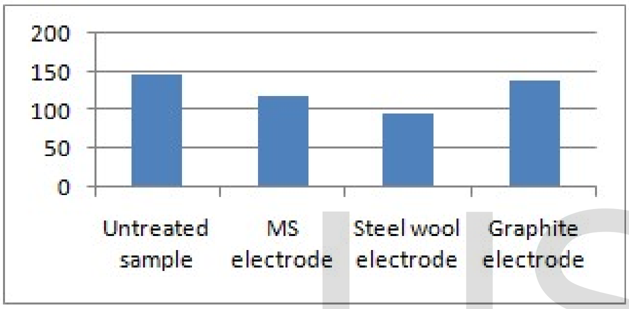


**Fig. 12** Removal efficiency of turbidity with different electrodes

As in the above cases , here also steel wool have shown better removal efficiency, then MS and graphite has shown least removal efficiency.

## CONCLUSION

Electrocoagulation being an efficient process to treat effluents is widely used in various industrial waste water treatment . Here the dairy effluent from a regional dairy plant is selected for the treatment. The electrocoagulation is done with mild steel, steel wool and graphite are used as electrodes with voltage varying from 5 to 30 with a increase of 5 volts in each run.After treating with two ms electrodes the chemical parameters of the effluent seems to show an ambient decrease,where it took more than two hours for complete coagulation with 5 volts and more than half an hour with 30 volt. When two steel wool electrodes were used ,the chemical parameters has shown decrease from initial concentrations andfurther decrease than with ms electrodes. With steel wool electrodes it tookmore than two hours for complete coagulation with 5 volt and less than half an hour with 30 volt.When graphite is used as electrodes, time taken for complete coagulation keeps increasing than that of MS and steel wool even though the undesirable chemical parameters increases when compared with ms and steel wool electrodes. Thus from the experiments and results it could be concluded that steel wool can be used as a better alternative for the conventionally used electrodes of material iron, aluminiumetc which has shown good decrease in undesirable chemical parameters with time bounded experiment. Since electrocoagulation is an emerging innovative technology there can be several chances of further exploring of this method over various combinations of electrodes also.Since here the dairy effluent is considered, it can be concluded that the dairy effluent can be treated with electrocoagulation process with steel wool electrode in aeconomical, timely and effective manner.

## References

[1] A combined electrocoagulation- electrooxidation treatment for dairy wastewater. Chakchouk N Elloumi C, Belaid S, Mseddi L ChaariM-Kallel (2017).

[2] Assesment of Physico-chemical parameters of dairy wastewater and isolation and characterization of bacterial strains in terms of cod reduction .ChatterjeeSreemoyee and PugahtPriti

[3] BOD/COD A Measure of dairy treatment efficiency A case study. Leena A V, Dr C Meiaraj, Dr N Balasundaram(2016)

[4] Dairy Industry Wastewater Sources, Characteristics ans its Effects on Environment, Bharati S Shete A and N.P Shinkar B A(2013).

[5] Dairy wastewater treatment in continuous stirred tank electrochemical reactor (CSTER). Vikas k Sangal, Neetu Singh PoonamKumari, Jai PrakashKushwaha (2017).

[6] Electrochemical treatment of dairy effluents using aluminium electrodes. C B Shivayogimath, Praveen Methi (2015)

[7] Performance evaluation of the evaluation of the wastewater treatment plant of Pelareh Dairy Industry, Iran. ElnazMohebi-Fard,MahdiReyahiKhoram, SoheilSobhanArdakani (2015).

[8] Physico chemical treatment of dairy industry wastewaters. TanerYonar, OzgeSivrioglu and NihanOzengin (2017).

[9] Removal of TSS from Dairy Wastewater by Hybrid Ironbased Electrocoagulation with Nanofilteration Membrane Processes. Masoud-Kianmehr, AlirezaKianmehr, MahshidAskarizadeh, EhsanShekarian (2014).

[10] Treatment of Dairy Industry Wastewater using Electrocoagulation Technique, Dr C.B Shivayogimath, Vijayalaxmi R Naik (2014)

[11] Treatment of Dairy Wastewater by Electrocoagulation process. Komal S Meshram, Dr .Arif Khan (2019).