Treatment of Dairy Industry Wastewater using an Electrocoagulation Process

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ABSTRACT

In this study, the treatment of dairy industry wastewater using an electro-coagulation process has been investigated. The COD removal percentage was considered as the efficiency index of the procedure. This study has been conducted with the aim of optimizing the factors affecting the process of COD reduction or removal which include contact time (0 - 120 min), voltages (20, 10 and 30v), electrode gaps (2, 4 and 6 cm) and electrode materials (iron, aluminum and stainless steel). It was observed that the removal efficiency is directly proportional to the electrode material, contact time and voltage and inversely proportional to electrode gaps. An optimal COD removal was achieved with the iron electrode and a time, gap and voltage of 120 min, 2 cm and 30 V, respectively.

Key words: treatment of wastewater, dairy industry, iron electrode, electrochemical.

Introduction

Dairy industry 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 wastewaters and purification of the same has always been challenging. Thus many research studies have been conducted with this aim. 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 dairy wastewater with an increased rate of dissolved oxygen depletion, a decrease in the pH level due to the conversion of lactose to lactic 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. Therefore owing to the vast dispersal of the dairy industry across the country of Iran, a step must be taken toward treatment of the produced waste to prevent pollution from damaging our living environment [1].

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 [2-5]. 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 surface charge of the colloidal particles reduces to a point where they can overcome the vandervalce forces in between and allow coagulation to occur [6].

The electrochemical process is characterized as being easy to use, having simple equipment, being easy to operate, having a good settling ability of produced sludge, and being able to reduce operating costs and to lower TDS in the wastewater compared with standard chemical procedures [7]. This procedure is used in the treatment of wastewaters from the dairy industry, textile industry, restaurants, laundries, municipalities and alcohol distillation plants. Kan and his colleagues believe that three main processes occur serially during EC which are:

(a) Electrolytic reactions at electrode surfaces.
(b) Formation of coagulants in the aqueous phase.

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(c) Adsorption of soluble or colloidal pollutants on coagulants, and removal by sedimentation or flotation.

Materials and Methods

This research is a descriptive, analytical and practical study carried out in order to investigate the effect of a continuous electric current on the pollution index (COD) in wastewater samples. A 1500-mL glass beaker was used as a reactor vessel. After the addition of wastewater to the beaker, the electric current flowed through different electrodes in variable voltages and times. Before and after each run, the COD value was determined. The wastewater samples used in this study were taken from the natural wastewater collection channel at Dr. Movahed factory in Bojnourd Industrial City.

Aluminum, iron and stainless steel plates (15.0 x 4.0 cm) were used as electrodes and a 15% HCl (by mass) solution was used to clean the electrodes before beginning the experiment. Electrode combinations were chosen as Fe-Fe, Al-Al, St-St in this experiment. The experiments were carried out separately at three voltage ranges (10, 20 and 30 V) with a variable contact time for each series of electrodes. One sample was taken every 10 min from the beaker – considering the selected contact times for these experiments – and after filtration its COD value was determined using a COD reactor ET125. Other tools used in the experiment consisted of: an alternate/continuous transformer (regulated DC power supply - model 8303) for providing power and a multimeter for measuring voltage and current and also a magnetic stirrer (VELP SCIENTIFICA MODEL) with a stirring speed of 50 rpm for homogenizing. All experiments were done at room temperature (around 20°C).

Wastwater Under Investigation:

Wastewater contamination charges may vary during a day due to product variety, production volume and the cleaning of containers, boilers, floors, etc. Thus wastewater COD and BOD values change during a day. For experiments to be more accurate and less error-prone, a separate sample of wastewater was used with each sample electrode.

Fig. 1: Flocs (coagula) formation during electro-coagulation process

Fig. 2: A view of an experiment performed using the electrochemical method

Table 1: Analysis of the raw wastewater samples collected from the factory for the aluminum, iron and stainless steel electrodes

<table>
<thead>
<tr>
<th>Analysis of the collected raw wastewater sample for the aluminum electrode</th>
<th>Analysis of the collected raw wastewater sample for the stain steel electrode</th>
<th>Analysis of the collected raw wastewater sample for the iron electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported value</td>
<td>Wastewater parameter</td>
<td>Reported value</td>
</tr>
<tr>
<td>Dark</td>
<td>color</td>
<td>Dark</td>
</tr>
<tr>
<td>7.5</td>
<td>pH</td>
<td>7.4</td>
</tr>
<tr>
<td>13</td>
<td>T (°C)</td>
<td>15</td>
</tr>
<tr>
<td>1.2</td>
<td>DO (mg/L)</td>
<td>1.1</td>
</tr>
<tr>
<td>1560</td>
<td>EC (µs/cm)</td>
<td>1810</td>
</tr>
</tbody>
</table>
Results and Discussion

Graph 1: Results obtained from COD removal at voltages and times under study with iron electrode.

Graph 2: Results obtained from COD removal at voltages and times under study with aluminum electrode.

Graph 3: Results obtained from COD removal at voltages and times under study with stainless steel electrode.

Graph 1 indicates that COD value of wastewater has declined from 1605 to 285 with an increase in contact time (to 120 min.) at 30 Volts. A COD removal efficiency of 82% was obtained in this condition. At the beginning of the graph one can see a steep slope because organic materials are more abundant early in the EC process. This is due to the fact that generated iron hydroxides from the corrosion of the anode form complexes with ions occurring in the wastewater therefore rapidly removing COD. As is illustrated in Graph 2, an 80 min. contact time and 20V voltage for aluminum electrode led to a decline in COD value from 1506 to 446. COD removal efficiency in this condition is equal to 71% whereas a COD removal efficiency of 79% was achieved by increasing contact time to 120 min and at a voltage of 30 V. The results in the above graphs show that removal efficiency has increased with an increase in applied voltage. In fact the maximum and minimum removal efficiency was
obtained with iron and stainless steel electrodes respectively, at the input voltage of 30 V. Density of bubbles increases and their size decreases with an increase in current density resulting in a greater, faster and further removal of pollutants. A greater amount of hydroxide flocs was produced by increasing the electric current causing an efficient COD removal. The graphs show an increase in COD removal percentage with an increase in contact time as per Faraday's Law of Electrolysis which states that the mass of a substance deposited at an electrode during electrolysis is directly proportional to the quantity of charge passed through the electrolyte. Therefore increasing the contact time in the electrocoagulation process gives rise to a higher concentration of free ions inside the system and consequently an increased flocs and removal efficiency.

In an electrochemical process, the selected electrode material has a considerable impact on the removal process. Kobia and his colleagues investigated the use of EC technology with iron and aluminum electrodes in order to treat textile industry wastewater. From a COD removal efficiency and energy point of view, iron excels aluminum as a sacrificial electrode [8,9]. Thus, a selection of the proper electrode material is of great importance.

Graph 4: Analysis of the effect of electrode gaps on COD removal efficiency with iron electrode at 30 V, 120 min contact time and 500 rpm stirring speed

Graph 4 illustrates that applied voltage has been increased proportionally with an increase in the gap between each cathode / anode pair. The reason is because solution resistivity increased as a result of increased electrode gaps in a constant amount of electrolyte. At 120 min. contact time, an increase in electrode gaps from 2 cm to 6 cm resulted in a reduction of removal efficiency from 82% to 69% which is due to a reduction in the concentration of ions and a consequent decrease in electrostatic attraction.

Conclusion:

Considering the result, COD removal efficiency is directly proportional to contact time and input voltage and inversely proportional to electrode gaps. The result also showed that remediation efficiency has increased to 82% with iron electrodes, 2 cm electrode gaps, 120-min. contact time and 30V voltage. As a final conclusion it can be said that electrocoagulation is an efficient process for removing contamination charge index (COD) and can be used as a fast, easy, economical and low cost way needing less equipment and limited space.

References

