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Removal of NTU from Dairy Wastewater by Hybrid Aluminium-based Electrocoagulation with Nanofiltration Membrane Processes

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ABSTRACT

In this study, treatment of dairy wastewater using a electrocoagulation – nanofiltration (EC-NF) hybrid system was investigated. The performance of electrocoagulation (EC) using aluminium-stainless steel electrodes as a pretreatment step for the nanofiltration process was studied. At high voltage and residence time, the extent of anodic dissolution of aluminum increases, resulting in a greater amount of precipitate for the removal of pollutants. At the optimum residence time and voltage, NTU removal by the electrocoagulation process was 98.5%. The effect of operating pressure in the nanofiltration process on NTU removal was investigated. The experiments were carried out at three pressures of 9, 12 and 15 bar. Removal of NTU increased with increasing applied pressure. The reported results demonstrate that an EC – NF hybrid system can be a promising candidate for dairy wastewater treatment.

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INTRODUCTION

Membrane technology has provided an important solution in water pollution treatment recently. However, the accumulation of colloids on the surface or inside the pores of the membrane, i.e. the colloidal fouling, is leading to severe energy loss during filtration, and consequently to high operational costs that limit the application of the membrane technology. The addition of a coagulant prior to membrane filtration has been adopted to improve product water quality and reduce membrane fouling. At the same time, electrocoagulation (EC) is an alternative method. EC has been widely used in oily, dye and textile wastewater, potable water, dairy effluents and landfill leachate, to study the removal of organic matter, heavy metals, fluoride, etc [1].

Electrocoagulation involves the generation of coagulants in situ by dissolving electrically either aluminium or iron ions from aluminum or iron electrodes, respectively. The metal ions generation takes place at the anode, and hydrogen gas is released from the cathode. The hydrogen gas would also help to float the flocculated particles out of the water. The materials can be aluminium or iron in plate form or packed form of scraps such as steel turnings and millings [2].

In this method, a convenient current is imposed on soluble anodes like aluminum, iron or their alloys in an electrochemical cell acting as the reactor for the experiment separated by filtration, depending upon their density. The electrocoagulation results in the dissolution of the electrode to yield metal ions (Fe2+, Fe3+ or Al3+) which are active coagulants precursors involved in the neutralization of the negative charges on the colloids of the effluent. These metal ions then react with the hydroxyl colloidal particles is specific in each of these processes [3].

EC has been applied to treat water containing foodstuff wastes, oil wastes, dyes, treat wastewater from pulp and paper industries, yeast wastewater, urban wastewater, restaurant wastewater, tar sand and oil shale wastewater, nitrate containing wastewater solutions, arsenic containing smelter wastewater, mining and metal-processing industries, suspended particles, chemical and mechanical polishing waste, organic matter from landfill leachates, defluorination of water, synthetic detergent effluents, mine wastes and heavy metal-containing solution [4, 5].

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Electrocoagulation removes the small colloidal particles efficiently in comparison with the conventional techniques, because the small charged particles have greater probability of being coagulated and destabilized by the electric field that forces them in motion. Simultaneously, gas bubbles are produced due to electrolysis, which can enhance flotation. Floc formed by EC is similar to the floc formed by chemical coagulant, but the EC floc contains less bound water and tends to be much larger, more stable, and acid-resistant. Therefore, it can be separated faster by filtration. A fewstudies have investigated hybrid electrocoagulation membrane processes, which have shown to be highly efficient in removing a large range of pollutants from water, such as virus, nickel, selenium, and silica [1].

Results of previous studies indicate that use of EC pretreatment for membrane processes can be very efficient and leads to reduced fouling, increased removal of impurities, reduce energy consumption and therefore reduce costs [1, 6-11].

MATERIALS AND METHODS

The wastewater used in this work was taken from the local dairy factory in Iran (Golestan province), with turbidity (NTU) equal to 316 (mean value). All materials were purchased from Merck.

2-1- Electro-Coagulation (EC):

The experiment was setup in the static method where the EC and wastewater batch test are performed in a glass cell (volume 5,000 mL). Three anodes and three cathodes made of aluminium and stainless steel plates were connected in parallel and the monopolar to a digital DC power supply (0-50 V, 30 A). The total effective electrode area was 400 cm2.

At EC process residence time and voltage parameters were studied. After NTU removal amounts were measured in each case. Different scenarios of experiments can be seen in Table 1.

Table 1: Different scenarios of experiments.

Number	Residence Time (min)	Voltage (V)	The Anode Electrode
1	20	5	Al
2	20	10	Al
3	20	15	Al
4	30	5	Al
5	30	10	Al
6	30	15	Al
7	40	5	Al
8	40	10	Al
9	40	15	Al

Later effluent from the EC with the highest percentage removal by nanofiltration process was purification.

2-2- Nanofiltration (NF):

The nanofiltration membrane (NF2) was used in this investigation. The membrane was supplied by Sepro. Filtration experiments were performed with a cross-flow filtration setup. The cross-flow cell housed flat sheet membrane pieces with an effective area of 28 cm2. The experiments were carried out at three pressures of 9, 12 and 15 bar.

2-3- Turbidity measurements:

Turbidity (NTU) measurements were made using a Jenway 6035 Turbidimeter. Before each measurement, samples were shaken and turbidity cells carefully wiped to get rid of dust particles and fingerprints. The turbidimeter was calibrated after each measurement.

RESULTS AND DISCUSSION

3-1- Effect of voltage and residence time on the EC:

The effect of residence time and voltage in the EC process on the NTU removal efficiency was investigated. Fig. 1 shows the change of NTU removal efficiencies as a function of residence time and voltage. It is clear that NTU removal efficiency is increased from 96.2% at 20 min residence time to reach a maximum of 98.5% at 40 min residence time (at constant voltage equal to 15 V). The same is true for the effect of increasing residence time on the efficiency of NTU removal at another voltage.

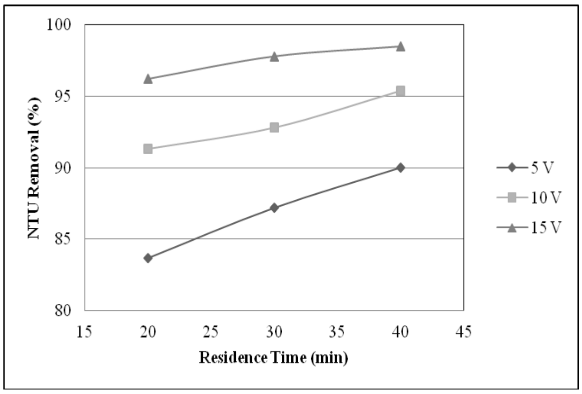

Fig. 1: Change of NTU as a function of residence time and voltage.

Also, the relationship between the NTU removal efficiency and voltage is depicted in Fig. 1. The figure shows that as the voltage increased from 5 to 15 V, removal efficiencies increased from 90.0% to 98.5% and from 87.2% to 97.8% and from 83.7% to 96.2% for the residence times of 40, 30, and 20 min, respectively. This is ascribed to the fact that at high voltage and residence time, the extent of anodic dissolution of aluminum increases, resulting in a greater amount of precipitate for the removal of pollutants. Moreover, bubble generation rate increases and the bubble size decreases with increasing voltage and residence time. These effects are both beneficial for high pollutant removal.

The highest NTU removal efficiency (98.5%) occurred at a voltage of 15 V and residence time 40 min.

3-2- Effect of operating pressure on the performance of NF:

After pretreatment by coagulation process, effluent with the highest percentage removal was purified by nanofiltration process at pressures of 9, 12 and 15 bar.

The removal of NTU as a function of applied pressure is shown in Figs. 2. As illustrated in Fig. 2, removal of NTU increased with increasing applied pressure. The concentration of impurities in the permeate decreased with increasing flux. When the applied pressure was increased, permeate water flux through the membrane increased, while the impurities flux remained virtually unchanged.

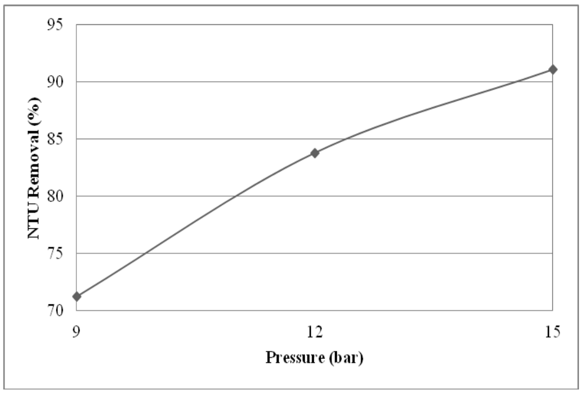

Fig. 2: Change of NTU as a function of pressure.

The results show that with the increase of operating pressures, increases removal efficiency and water flux. In contrast, operating costs increased due to higher energy consumption.

Conclusion:

This study examines the use of EC-NF hybrid system for the NTU removal of dairy wastewater. The effect of key operational parameters including residence time and voltage on the performance of the EC process was investigated. Integration of EC and NF was successfully used in removal of NTU in a dairy wastewater. By increasing residence time and voltage, the extent of anodic dissolution of aluminum increases, resulting in a greater amount of precipitate for the removal of pollutants. Moreover, bubble generation rate increases and the bubble size decreases with increasing voltage and residence time. These effects are both beneficial for high pollutant removal. As a result, NTU removal efficiency increases. The EC process was optimized with respect to operating parameters. The percentage of NTU removal at the optimized condition was found to be 98.5% (At a voltage of 15 V and residence time 40 min). Further refinement was brought about by nanofiltration. The effect of operating pressure in the nanofiltration process on NTU removal was investigated. The experiments were carried out at three pressures of 9, 12 and 15 bar. Removal of NTU increased with increasing applied pressure. The results show that with the increase of operating pressures, increases removal efficiency and water flux. In contrast, operating costs increased due to higher energy consumption.

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