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Effects of operational parameters on the removal efficiency of non-ionic surfactant by electroflotation

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ABSTRACT

Due to their wide use and resistance to biodegradation, untreated surfactant solutions were commonly found in large quantities in industrial or urban wastewaters. In this paper, we present the results of separation of non-ionic surfactant (Tween 20) from aqueous solution by electroflotation (EF) using two stainless steel electrodes. Our goal was to investigate the influence of physicochemical and electrolysis parameters on the performance of EF system for surfactant recovery. Thus, the efficiency of separation of Tween 20 reached 74.79% at neutral pH and a current density of 8.42 mA/cm^2. The initial concentration of the effluent was 10 CMC. Therefore, the results of this study show that EF is highly attractive for the treatment of wastewater containing organic pollutants.

Keywords: Surfactant; Tween 20; Removal; Electroflotation; Efficiency

1. Introduction

Surfactants are widely used in many industries such as detergents, personal care products, food industries, fire fighting and others [1]. However, under anaerobic conditions, they are not biodegraded and affect the aquatic life by acting with some other toxic chemicals present in wastewater, and increasing negative effects on the environment [2]. Therefore, the development of novel water treatment processes to more effectively remove surfactants from wastewater is important in reducing their environmental impact. In this way, many studies and techniques were used, among theme, the simultaneous use of ozone and activated carbon [3], membrane technologies such as ultrafiltration [4], chemical precipitation, chemical coagulation and photocatalytic degradation, witch are often costly and may possibly create secondary pollution caused by excessive use of chemicals, or the destruction of surfactants [5].

Recently, there is a need to identify new technologies that achieve technically and economically efficient separation of surfactants from aqueous solutions. For this purpose, electrochemical processes are playing more prominent roles in the treatment of wastewater containing organic pollutants. Electroflotation (EF) process, witch is the combination of chemical and electrochemical processes seems to be one among others processes enable for the removal of surfactants from wastewater [6].

Surfactants containing hydrophobic and hydrophilic groups have a fundamental property which is their strong tendency to adsorb at the air/liquid interface. This property makes that the separation of these molecules can be carried out by the introduction of gas bubbles into the treated fluid. It was shown [6,7] that it was

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possible to separate these molecules while carrying out a fractionation by foaming. Phenomenon of adsorption at the air/liquid interface is based on an increase in the surface area formed by the gas bubbles, and which is thus available that the adsorption of surfactants present in the solution occurs, with a notable lowering of the surface tension.

EF consists mainly of the electrolysis of aquatic part and the separation by flotation of contained suspended matter with the help of finely dispersed micro-bubbles, due to the generated hydrogen and oxygen gases [8]. This process, due to the fine bubbles production, as well as to the other advantages (e.g. the passage of electric current through the solution, is sensitive to the temperature, current density, pH, concentration of the treated solution and additives [9–11].

The purpose of this present study is to investigate the removal efficiency of a non-ionic surfactant (Tween 20) by EF. Series of batch experiments were conducted with different concentrations of surfactant greater than the critical micelle concentration (CMC). Effects of several parameters on the separation efficiency were investigated, such as time of treatment, pH, current density, surfactant concentration and concentration of salt. For a good operating mode, just one parameter was varied and all the others were been fixed.

2. Material and methods

The non-ionic surfactant used in this study is Tween 20. Its CMC is about $8.04 \cdot 10^{-5}$M (60 mg/l) at 20 °C. It was purchased from Riedel-de-Haën. Sodium sulphate (Na_2SO_4, 99.5% purity), and sulfuric acid (H_2SO_4, 98%), sodium hydroxide (NaOH, 98% purity) were purchased from Riedel-de-Haën. All reagents were used without further purification, and were prepared in distilled water at room temperature.

Experiments were conducted in batch reactor with two stainless steel electrodes connected in parallel. There were fully submerged horizontally with 1.5 cm spacing; the cathode is perforated with 105 holes with 1.5 mm drill bit. These electrodes of 2 mm thickness are connected to a power supply source. The samples of the effluent are introduced into the cell at 23 °C. The pH of the solution was adjusted by adding the appropriate amount of NaOH or H_2SO_4 to the solution. After each 5 min of treatment, samples were removed from the solution for the determination of the residual concentration of surfactant. An UV/VIS spectrophotometer (UV-mini 1240 Shimatzu, Japan) was used for the determination of surfactant concentration.

The removal efficiency of the electroflotation process (Re%) was calculated by the following expression.

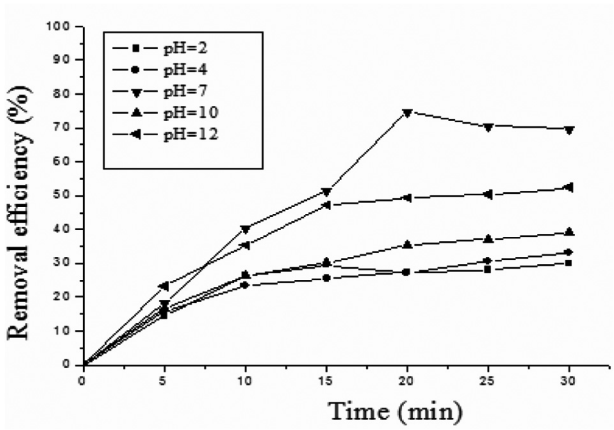

Fig. 1. Removal efficiency as a function of time at different pH ([Tween 20] = 10 CMC, [Na_2SO_4] = 7 g/l, $i = 8.42$ mA/cm^2).

$$\mathrm{Re} = \frac{C_0 - C_\mathrm{f}}{C_0} \times 100$$

Where C_0 and C_f are the initial and final concentration (mg/l) of the treated solution.

3. Results and discussion

3.1. Effect of pH

The electrolysis time is an important parameter, as an economic factor (energy consumption), and it can affect the removal efficiency of the effluent. pH is also an important parameter in chemical and electrochemical process. The effect of pH on the surfactant removal efficiency is shown in Fig. 1. The variation in residual concentration of surfactant decreases rapidly before the first 10 min of the treatment. Thus, the removal efficiency of surfactant reached a constant value after 20 min of treatment. Also, the kinetic of the EF is very fast at the first 10 min, and a significant decrease is observed after 15 min. At neutral pH, the removal efficiency reached an optimal value. Hence, a significant decrease is observed when pH is less or higher than 7 (Fig. 2), because the mechanism of formation of gas bubbles is disturbed at the electrodes giving rise to their size and their distribution, witch affect the EF process, and consequently a decrease in the removal efficiency is observed [12].

3.2. Effect of current density

The effect of current density on the removal efficiency is shown in Fig. 3. After 15 min, by increasing the current density from 2.1 to 8.42 mA/cm^2, an optimal value is observed where the removal efficiency reached 74.79% at 8.42 mA/cm^2 (Fig. 4), because the

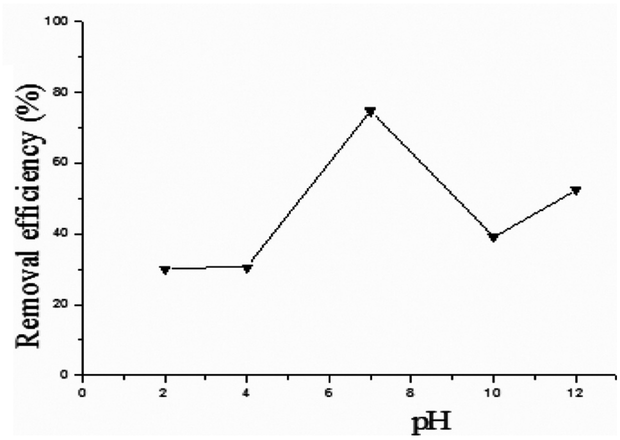

Fig. 2. Effect of pH on the removal efficiency ([Tween 20] = 10 CMC, [Na_2SO_4] = 7 g/l, i = 8.42 mA/cm^2).

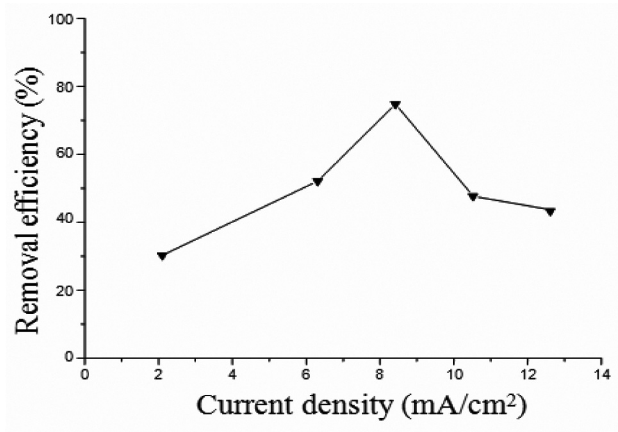

Fig. 4. Effect of current density on the removal efficiency ([Na_2SO_4] = 7 g/l, pH = 7, [Tween 20] = 10 CMC).

attachment step between gas bubbles inside the cell and the effluent is enhanced, and more surfactants are carried up at the surface by gas bubbles [13] and a droop is observed when the current density is higher. Therefore, higher current density has a negative effect on the EF process [14], because it induces a formation of large gas bubbles, giving rise to turbulence phenomenon. For another hand, increasing current density above the optimum value greatly increases the number of gas bubbles, and they will coalesce instead to be attached to the effluent [15].

3.3. *Effect of salinity (Na_2SO_4)*

The results shown in Fig. 5, indicate that the removal efficiency of the effluent, increased by increasing the salt concentration. There is a significant enhancement on surfactant removal when the concentration of Na_2SO_4 increases from 1 to 7 g/l, so it is possible to remove 74.79% at neutral pH for 2 min of treatment at a current density of 8.42 mA/cm^2. Also, when the salinity is higher than 7 g/l, a significant increase in the residual concentration of surfactant was observed. Hence, the high salt concentration disturbs the EF process, by inducing a turbulence effect in the solution and leads a droop on the removal efficiency. So, the high salinity decreases the size of hydrogen bubbles [15]. Then the smaller bubbles are less buoyant than larger ones witch rise slowly to the surface, yielding an improvement on the surfactant removal [16,17].

3.4. *Effect of surfactant concentration*

From Fig. 6, it can be seen that the removal efficiency enhanced when the concentration of the

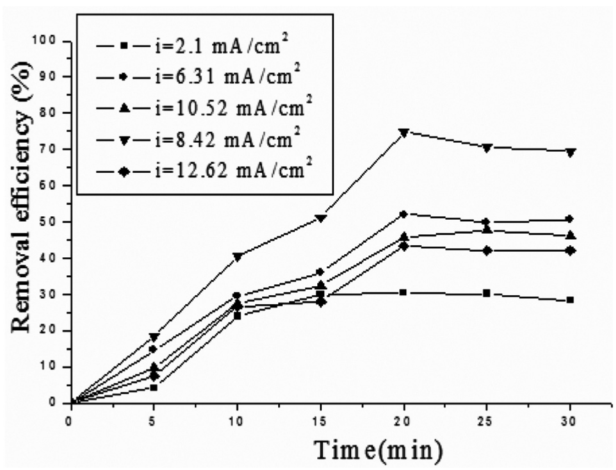

Fig. 3. Removal efficiency as a function of time at different current densities ([Na_2SO_4] =7 g/l, pH = 7, [Tween 20] = 10 CMC).

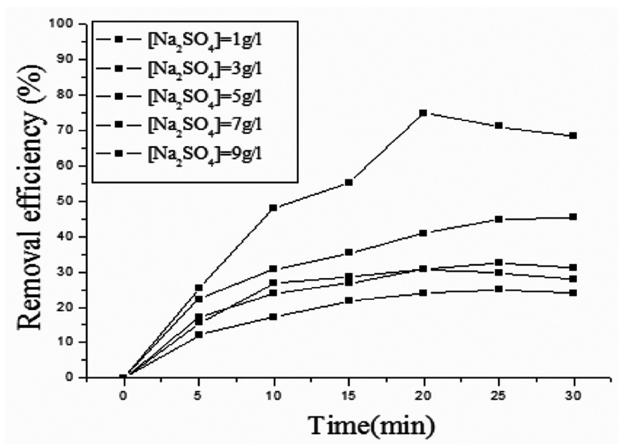

Fig. 5. Removal efficiency as a function of time at different salinities ([Tween 20] =10 CMC, i = 8.42 mA/cm^2, pH = 7).

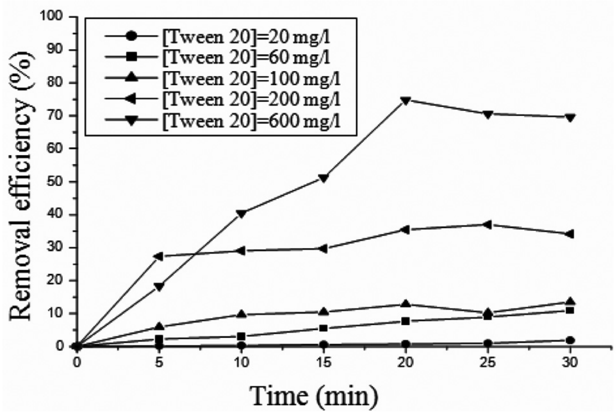

Fig. 6. Effect of surfactant concentration on the removal efficiency. (pH = 7, $[Na_2SO_4]$ = 7 g/l, i = 8.42 mA/cm^2).

surfactant is greater than the CMC. For an initial concentration of 60 mg/l, only 10% of surfactant was removed after 30 min of treatment, this amount increase significantly at 74.79% for 20 min of treatment when the concentration was about 600 mg/l (10 CMC). Thus, the EF process seems to be a good technique to remove surfactant from wastewater when its concentration is higher than CMC and with less energy consumption.

5. Conclusion

Electroflotation process was used for the removal of non-ionic surfactant (Tween 20) from wastewater. The effects of important parameters such as treatment time, pH, current density, concentration of effluent, and salinity were investigated. The results of our previous experiments showed that surfactant removal efficiency is enhanced at the first 20 min of treatment, at neutral pH. Thus, increasing current density is unsuitable for the EF process by the formation of large gas bubbles witch will coalesce instead to be attached to the effluent. Although, high ionic strength induces turbulence effects in the solution and provokes a decrease in the removal efficiency. An optimal efficiency value (74.79%) was obtained for a density of 8.42 mA/cm^2 and a salt concentration of 7 g/l. As it is indicated above, the EF process is more benefic for a very concentrated solution of effluent. In our case, the process was very efficient for surfactant concentrations higher than CMC.

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