The Effect of Operating Conditions on Simultaneous Removal of Phosphate, Nitrate and COD from Laundry Wastewater by Electrocoagulation Using Aluminum Electrodes

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Introduction

Phosphorus is an important mineral element for organisms' growth. Nowadays, the use of detergents and cleaners has become one of the essentials of human life. Since these materials enter into the sewage systems, the existing polyphosphate reacts with water and gradually changes to phosphate ions and cause environmental problems. Electrocoagulation is an electrical treatment process which has been progressively applied to treat water and wastewater, recently. In this process, the removal of pollutants takes place with applying the electrical current to the electrodes. When aluminum electrodes are used, the aluminum dissolves at the anode and hydrogen gas is released at the cathode. Overall, electrocoagulation is an electrochemical technique with many applications, in which a range of unwanted dissolved particles and suspended mater can be effectively removed from an aqueous solution by electrolysis.

When aluminum is used as electrode material, the reactions that occur are as follows:

At the cathode: $3H_2O + 3e^- \rightarrow \frac{3}{2}H_{2(g)} + 3OH^-$

At the anode: $Al \rightarrow Al^{3+} + 3e^-$

In the solution: $Al^{3+}{}_{(aq)} + 3H_2O \rightarrow Al(OH)_3 + 3H^+{}_{(aq)}$

As seen in the above reactions, electrocoagulation is a combination of oxidation/reduction, flocculation and flotation. Electrocoagulation occurs in three steps. At the first step, coagulant has formed because of oxidation of anode. At the second step, pollutants are destabilized. At last step, destabilized matters are united. The aim of this study is to determine the effect of operation conditions in Simultaneous removal efficiency of phosphate, nitrate and COD from laundry wastewater by electrocoagulation method using aluminum electrodes.

Materials and methods

The monopolar electrocoagulation unit consists of an 850mL electrochemical glass-made reactor with two Al anodes and two Al cathodes. The length and width of each electrode is 140 mm and 60 mm, respectively. Total surface areas of anode and cathode are 336 cm^2. The distance between electrodes is variable in different experiments to find out the optimum distance. The applied voltage was kept constant by means of a power supply (DAZHENG PS-302D). Aluminum electrodes were polished using grinding papers to remove the thin aluminum oxide film after tests and then rinsed with soap water and deionized water prior to electrolysis. Digital apparatus was used to measure the current passing through the circuit and the applied potential, respectively. During the experiments, pH of wastewater samples was measured by a pH-meter (510 PC).

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Treated wastewater was collected over a desired period of time from the reactor and collected samples were filtered through a cellulose acetate membrane filter with the pore diameter of 0.45 μm prior to analysis.

Reactor was operated in batch mode. Wastewater used in the experiments was collected from one laundry house in east of Tehran. pH adjustments were conducted by HCl (1N) and NaOH (5 N); all chemicals used in the experiments were of analytic grade.

The analysis of phosphate was carried out using the yellow vanadomolybdophosphoric acid method according to the Standard Methods for the Examination of Water and Wastewater.

To select the reaction time, some preliminary tests were performed. For this purpose, the experiment was conducted for 90 min. Based on the results the reaction time of 60 min was selected.

The removal efficiency of COD, nitrate and phosphate from wastewater were studied for different operational conditions. The effects of pH, electrodes distances, electrical current density and reaction time on the efficiency of treatment of laundry wastewater were investigated. After selecting the reaction time of 60 min, by fixing other operational parameters, the effect of pH value was examined. The pH value distance between electrodes was optimized and then the optimal electrical current density was found out by conducting experiments in various current densities at fixed other operational conditions.

Results and discussion

Effect of initial pH

It has been established that the influenced pH is of vital importance in the performance of many electrochemical processes and chemical coagulation operations. Also, that the initial pH of the electrolyte is one of the important factors affecting the performance of electrochemical process particularly on the performance of electrocoagulation process.

Results show that the removal efficiency of phosphate was increased with increasing the initial pH value and the maximum removal efficiency of 99.93% was obtained at pH 7.0. The minimum removal efficiency of phosphate was 92.86% at pH 3. The decrease of removal efficiency at more acidic and alkaline pH was observed by many investigators and was attributed to an amphoteric behavior of Al(OH)3 which leads to soluble Al3+ cations (at more acidic pH) and to monomeric anions $Al(OH)_4^-$ (at alkaline pH). It is well known that these soluble species are not useful for water treatment. When the initial pH was kept neutral, all the Aluminum produced at the anode formed polymeric species ($Al_{13}O_4(OH)_{24}^{7+}$) and precipitated $Al(OH)_3$, leading to more removal Efficiency. In the present study, the results agree well with the results presented in the literature and the maximum amount of phosphate removal occurred at pH 7.0.

Effect of electrodes distance

One of the other parameters studied in removal of pollutants is the distance between the electrodes. In this case, four distances were studied (3, 5, 10 and 15 mm). Results showed that when the electrode distance increased, the voltage of cell increased too and the pollutant removal rate was increased, too. The optimum electrode distance was 10mm, in this study.

Effect of Current density

Current density is also an important operating factor for controlling the reaction rate in electrochemical processes. It is well known that the amount of current density determines the size of bubble production and affects the growth of flocs. Four current densities (3,6,9 and 12mA/cm^2) were applied to examine the effect of current density on the electrocoagulation treatment of laundry wastewater. Phophate, Nitrate and COD removal efficiencies at 3-12mA/cm^2 for 60 min were changed from 97.64-99.93% and 58.33–73.30% and 57.80–70.83% for Al electrode. It was further noted that there were minor differences in phosphate and nitrate removals at the higher current densities. More over, higher current densities caused electrical energy consumption and operating costs to be high. Therefore, current density at 12mA/cm^2 was chosen as an optimum current density for experiments. This was attributed to the fact that at high current densities, the extent of anodic dissolution of aluminum increased, terminating in a greater amount of precipitate for the removal of pollutants.

Kinetics of phosphate and nitrate removal

Kinetics of phosphate and nitrate removal was studied in this section. As known, pollutant removal rate depends on the ion produced, electrode material, electrochemical reactions and electrical flow rates.

Conclusions

In this investigation, electrochemical coagulation has been applied for phosphate, nitrate and COD removal, using Aluminum electrode to treat laundry wastewater.

Results showed that by using this method phosphate removal efficiency of 99.93% was achieved. Removal efficiency for nitrate was 67.85% and that was 70.83% for COD removal.

Optimal operating parameters such as initial pH, distance between the electrodes and current density in phosphate, nitrate and COD removal were as follows; pH=7, current density=12mA/cm2, electrode distance= 10 mm and reaction time= 60 min.

Key words

Electrocoagulation, Phosphate, Nitrate, COD, Wastewater treatment