Optimization of organic compounds removal from Wastewater by Electrocoagulation

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Original Article

Abstract

Introduction: As the most hazardous sewage, hospital wastewater contains various contaminants, and its uncontrolled discharge can seriously damage the environment. Bandar Abbas is located in an arid and semi-arid region; therefore, hospital wastewater should be treated through an appropriate and economic method. This study aimed to determine the efficiency of electrocoagulation with aluminum and iron electrodes in removal of COD from wastewater of Shahid Mohammadi Hospital of Bandar Abbas.

Methods: This analysis was performed in laboratory-scale through an incoherent method using a reactor which contained iron and aluminum binary and quaternary electrodes. A total of 55 samples of raw sewage of the hospital were examined and a total of 216 samples were analyzed to determine the parameters which were effective in the process. Samples (3 L) were immediately transferred to the laboratory after collection. COD removal was performed through electrocoagulation at pH 3, 7, and 11, voltages 10, 20, and 30, and reaction times of 30, 45, and 60 min. The results were analyzed using SPSS 16 through analysis of covariance.

Results: The data showed better performance of electrodes at 2 cm apart rather than 3 cm. The COD removal efficiency was increased by 6.2% when pH was decreased from 11 to 3 at optimum voltage of 30 V and reaction time of 60 min. The results showed that by increasing the reaction time from 30 to 60 min at voltages 10, 20 and 30, the efficiency of COD removal increased from 32.3% to 87.1%. Therefore, the highest efficiency of COD removal (87.1%) was obtained at optimal pH of 3, voltage of 30 V, and reaction time of 60 min with iron quaternary electrode.

Conclusion: Given the high efficiency of electrocoagulation as well as its simplicity and relatively low cost, it can be used for removal of COD from hospital wastewater.

Key words: Hospital - Wastewater – Electrocoagulation

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Introduction:

As a highly hazardous sewage, hospital wastewater contains pathogens including bacteria, viruses, and parasites, dangerous chemical compounds, pharmaceutical compositions, and radioactive isotopes. Protection of water resources in a country like Iran with a lot of climatic constraints is of great importance; therefore, it is necessary to treat the contamination sources such as municipal, industrial, and hospital sewage before disposal to receiving waters. In general, the most important objectives of wastewater treatment and control of environment contamination include prevention of infectious and chronic diseases, preservation of the environment beauty, and possibility of wastewater reuse (1). Hospital wastewater is one of the most dangerous types of sewage (2), and contains various microorganisms, indicating the importance of more attention to this source of contamination. If properly treated, hospital wastewater can be use for agricultural purposes (3).

Electrocoagulation is a wastewater treatment process performed electrochemically, in which direct current power is applied to remove contaminants from solution. In electrocoagulation, the coagulant is produced in situ through electrolytic oxidation of an anode made of a suitable material. Then the charged ion species are removed by providing the possibility of reaction with an oppositely-charged ion or with metal hydroxides produced in the wastewater (4).

Given simple equipments required, ease of operation, good capability for sludge sedimentation, less sludge production, production of bigger flocks than chemical treatment, no chemicals use, reduced secondary contamination by chemicals, cost-effectiveness, secure nature, and environment friendly, electrocoagulation technology is well accepted recently for wastewater treatment (5-8). Other features of this process include removal of various heavy metals, removal of chromium from liquid environments (9,10), removal of colloidal and suspended solids, cleavage of oil emulsions in water, removal of fat, oil, and grease, removal of organic compounds, destruction and elimination of bacteria, viruses, and cysts (5,6,8,11), removal of monoazo dye Acid Red (12), and removal of Orange dye (13). Electrocoagulation is an appropriate method for treatment of a wide variety of wastewater such as dairy sewage (14), removal of cyanide, BOD, and COD from olive oil wastewater (11), removal of COD from suspended solids (7), and removal of detergents from automotive industry wastewater (15).

Shahid Mohammadi Hospital of Bandar Abbas is one of the largest hospitals in Hormozgan Province with 450 approved beds and 23 wards. The hospital produces more than 1000 m^3 wastewater per day which is treated with an extended aeration activated sludge system. The system not only has a low COD removal efficiency, but also is not cost-effective in terms of energy. Therefore, this study aimed at treatment of wastewater of Shahid Mohammadi Hospital of Bandar Abbas with a simple and economic method and with higher efficiency. In this regard, the possibility of using electrocoagulation with aluminum and iron electrodes in removal of COD from the hospital wastewater was investigated.

Methods:

This analysis was performed in laboratory-scale through an incoherent method using a reactor which contained iron and aluminum binary and quaternary electrodes (Figure 1).

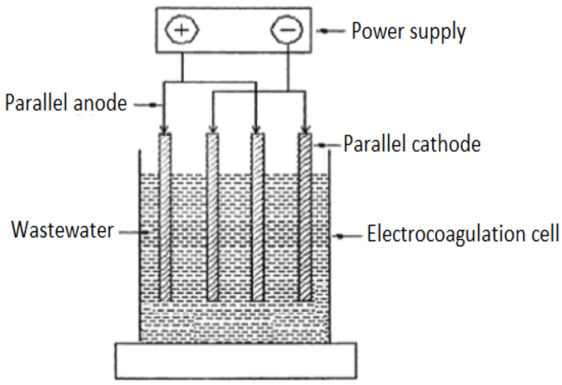

Figure 1. Schematic Design of Electrocoagulation Reactor

The samples were collected through the standard method from the hospital wastewater inlet, and their characteristics (COD, phosphates, nitrates, and turbidity) were measured. A total of 55 samples of raw sewage were examined and a total of 216 samples were analyzed to determine the parameters effective in process. Samples (3 L) were immediately transferred to the laboratory after collection.

The parameters evaluated in this process included the type of electrodes (aluminum and iron) in iron-iron, aluminum-aluminum, and aluminum-iron arrangements, the number of electrodes (2 and 4 metal plates), contact time (30, 45, and 60 min), voltage (10, 20, and 30 V), pH (3,7,11), and the distance between the two electrodes (2 and 3 cm). In these experiments, according to the transmitted voltage, current intensity ranged between 1 and 5 A. In each series of experiment, samples were taken from the reactor and COD was determined through titration (spectrophotometer DR5000) according to the standard procedure 5220. Turbidity was measured through nephlometry and phosphate with spectrophotometer DR5000 in optimal conditions, according to the standard methods 2130 and 4500-p, respectively. All tests were conducted at laboratory temperature range. The results were analyzed using SPSS 16 through analysis of covariance.

A 12×12×16 cm electrochemical chamber was constructed of 10 mm thickness glass with a volume of 2.25 L, and then 12×10×0.2 cm iron and aluminum electrodes, with one end connected to a direct power supply, were placed vertically 2 cm apart from each other. Wastewater was mixed with a magnetic stirrer at a constant rate of 100 rpm (Figure 2).

Figure 2. Pilot Used in Electrocoagulation Process

The electrodes were cleaned with hydrochloric acid 15% (w/v) before starting the experiments.

Results:

At first, the best voltage for removal of COD from the hospital wastewater was selected. According to Figure 1, COD removal during electrocoagulation with quaternary iron electrodes at pH 3, reaction time of 30 min, and voltages of 10, 20, and 30 V was 32.3%, 42.1%, and 54%, respectively, at reaction time of 45 min and voltages of 10, 20, and 30 V was 45.9%, 57%, and 69%, respectively, and at reaction time of 60 min and voltages of 10, 20, and 30 V was 64%, 75%, and 87.1% respectively; therefore, the highest percentage of COD removal was occurred at 30 V.

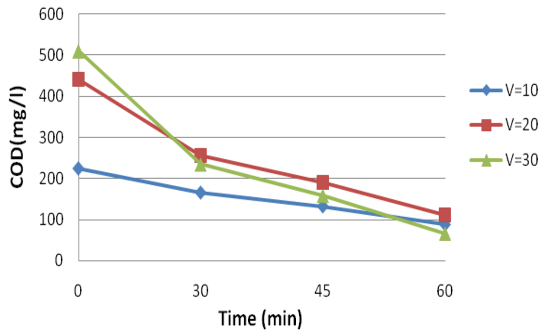

Figure 1. Reduction of COD Concentration versus Time during Electrocoagulation at Different Voltages with quaternary iron Electrodes (Fe-Fe) at Optimum pH 3

The effect of pH on wastewater COD reduction was studied. According to Figure 2, the COD removal rate during electrocoagulation with quaternary iron electrodes at 30 V and reaction time of 30 min was 54%, 47.1%, and 44% at pH 3, 11, and 7, respectively, at reaction time of 45 min was 69%, 62.2%, and 58.3% at pH 3, 11, and 7, respectively, and at reaction time of 60 min was 87.1%, 80.9%, and 76.2% at pH 3, 11, and 7, respectively; therefore, the highest percentage of COD removal was occurred at pH 3.

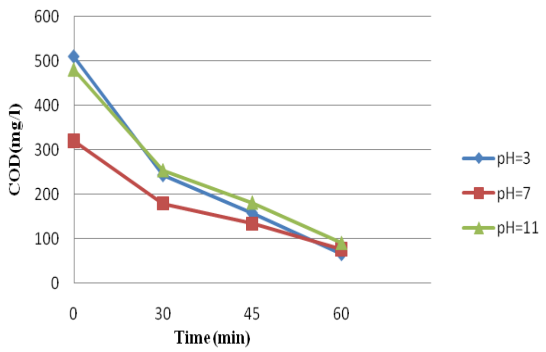

Figure 2. Reduction of COD concentration versus time during electrocoagulation at different pHs with quaternary iron electrodes (Fe-Fe) at optimum voltage of 30

After selecting the optimal pH and voltage, the impact of electrodes type and number on the removal process was examined. During electrocoagulation with binary iron-aluminum electrodes at optimum pH of 3 and reaction time of 60 min, the removal rate was 20%, 27%, and 36% at voltages 10, 20, and 30 V, respectively; it was 23%, 29.5%, and 39.1% with binary aluminum-aluminum electrodes, and 30.8%, 37.8%, and 42% with binary iron-iron electrodes. As can be seen, the maximum removal (42%) was occurred with binary iron-iron electrodes. At optimum pH of 3 and reaction time of 60 min, the removal rate obtained was 42%, 53%, and 66.7% with quaternary iron-aluminum electrodes, 42%, 59.2%, and 75.1% with quaternary aluminum-aluminum electrodes, and 64%, 75%, and 87.1% with quaternary iron-iron electrodes at voltages 10, 20, and 30 V, respectively. The results showed that quaternary iron-iron electrodes were the best combination of electrodes, and COD removal efficiency from the hospital wastewater was over 87%.

The next studied parameter was the effect of electrolysis time on removal process. At optimum pH of 3 and optimum voltage of 30 V, the removal rate of COD was 16.8%, 25.5%, and 36% with binary iron-aluminum electrodes, 19%, 27.1%, and 39.1% with binary aluminum-aluminum electrodes, and 25%, 33%, and 42% with binary iron-iron electrodes at reaction times of 30, 45, and 60 min, respectively (Figure 3).

The rate was 26.3%, 44.5%, and 66.7% with quaternary iron-aluminum electrodes, 35.1%, 51.1%, and 75.1% with quaternary aluminum-aluminum electrodes, and 54%, 69%, and 87.1% with quaternary iron-iron electrodes, respectively (Figure 4). The results showed that the removal rate increased by increasing the time. The highest and the lowest removal percent was obtained with quaternary iron-iron electrodes at 60 min (87.1%) and with binary iron-aluminum electrodes at 30 min, respectively.

By increasing the distance between the electrodes from 2 to 3 cm, the efficiency of COD removal from wastewater decreased from 87.1% to 68%. The removal of turbidity, phosphorus, and nitrate with quaternary iron electrodes at optimal conditions of 30 V, 60 min, and pH 3, was 100%, 93.57%, and 75%, respectively.

Evaluation of the Pearson correlation coefficient between the voltage and the rate of COD removal from wastewater represented a significant negative correlation ($P<0.01$), and COD levels decreased with an increase in voltage. There was also a significant negative relationship between voltage and electric current (EC). The results showed that the efficiency increased following an increase in voltage at fixed electrolysis time.

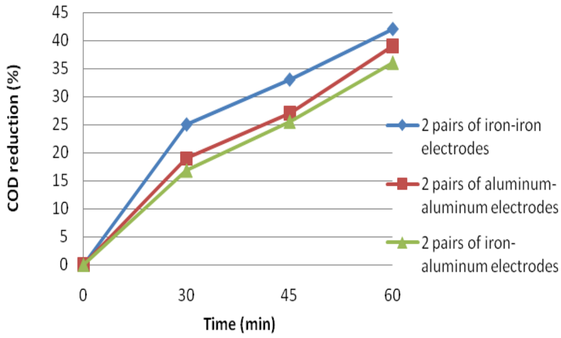

Figure 3. Reduction of COD concentration versus time during electrocoagulation with different binary electrodes at optimum voltage of 30 V and optimum pH of 3

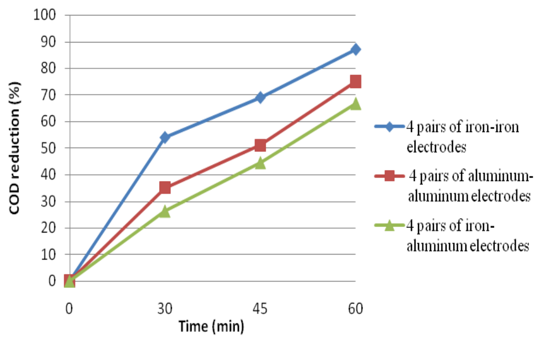

Figure 4. Reduction of COD concentration versus time during electrocoagulation with different quaternary electrodes at optimum voltage of 30 V and optimum pH of 3

Conclusion:

The results of this study showed that the number of electrodes had a great impact on the rate of COD removal, so that quaternary electrodes had a more removal rate than binary electrodes. On the other hand, the electrode material is effective in COD removal, and the highest removal was seen with iron-iron electrodes, and iron-aluminum electrodes had lower efficiency than iron-iron and aluminum-aluminum electrodes. The lowest removal rate was obtained from binary iron-aluminum electrodes.

There was a significant relationship between pH and COD removal, so that the COD removal rate decreased as pH increased. The results of this study are consistent with those of Rahmani and Samarghandi (2008) who showed that the efficiency of removal of Eriochrome Black T from wastewater is inversely related with increasing pH (17).

According to the results, increase in electrocoagulation time plays a crucial role in the process. During electrolysis, an anodic reaction takes place at positive electrode and a cathodic reaction at negative electrode. The released ions neutralize electrically charged particles which then coagulate. The removal efficiency directly depends on the concentration of ions produced by the electrodes, and the concentration of ions produced increases by increasing electrolysis time; as a result, hydroxide flocks increase. The results showed the highest COD removal rate was at 60 min. In other studies, the effect of electrolysis time has been also observed. According to the studies of Mahvi et al. for removal of chromium (10), Rahmani and Samarghandi (2008) for removal of color and COD (16,17), Jey et al. for laundry wastewater treatment (18), and Irdmaz et al. (2006) for removal of phosphate from wastewater, the efficiency is increased by raising electrolysis time (18,19). Pearson correlation coefficient showed that the relationship between COD removal and electrolysis time was significant, so that the amount of COD reduced by increasing electrolysis time ($P<0.01$). There was also a significant positive correlation between COD output and EC ($P<0.01$).

To determine the effect of electrode type on the removal, the experiments were performed at similar conditions in terms of voltage, time, pH, and the distance between the plates, through changing the electrodes. The results of this experiment showed that the type of electrodes has affected the COD removal efficiency. So that in constant optimum conditions of pH 3, voltage of 30 V, and electrolysis time of 60 min, the COD removal rate declined from 87.1% to 75.1% with quaternary electrodes of iron-iron and aluminum-aluminum. Also, the rate of COD removal in quaternary electrodes of iron-aluminum was reduced to 66.7%. According to the results, binary electrodes had a similar trend, so that the highest removal rate was occurred in iron-iron electrodes and the lowest in aluminum-iron electrodes.

The results of this study showed that the highest rate of removal of COD from wastewater occurred with iron electrodes. Shingil et al. concluded in their study that the highest removal of COD from wastewater can be achieved with iron electrodes (14). The studies of Aven et al. also showed that iron electrode was more effective than aluminum in the removal of COD and turbidity (11). While Irdmaz et al. showed higher removal efficiency with aluminum electrode than iron electrode (20).

Since the economic estimate is an important factor in choosing the appropriate treatment method, optimization of electrocoagulation process was evaluated in terms of the amount of electrical energy. Based on the results, the electrical energy used during electrocoagulation at optimum conditions was 30.6, 47.4, and 52.5 Watt-hours per liter for iron-iron, aluminum-aluminum, and iron-aluminum electrode pairs, respectively. Since the electrical energy consumed in iron-iron electrodes was lower than other arrangements and given that COD removal was more efficient, iron electrode is more economical. Bayramoghlu et al. (2006) found similar results, i.e. iron-iron electrodes costs less energy than iron-aluminum electrodes (21). In addition, studies conducted by Kubaya et al. (2008) showed that iron electrode is more effective than iron-aluminum electrode in terms of TOC and COD removal as well as the running cost of process (22). Finally, it can be concluded that electrocoagulation is a reliable, flexible, fast, effective, and economic treatment method for hospital wastewater.

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