

Short Communication

Disinfecting Poultry Slaughterhouse Wastewater Using Copper Electrodes in the Electrocoagulation Process

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Abstract

Insufficiencies and deficiencies in slaughterhouses could adversely affect public health. Wastewater from slaughtering, along with high microbial pollution, results in serious pollution to the surrounding environment if not treated. This study sought to investigate the efficiency of the electrocoagulation process using copper electrodes in the disinfection of poultry slaughterhouse wastewater without any initial controlling. The physical and chemical properties of samples of wastewater taken from a poultry slaughterhouse were first analyzed. Then the samples were subjected to the electrocoagulation process using copper electrodes in potential differences of 10, 20, and 30 V over a period of 60 min. Then the removal efficiency of total coliforms was examined in accordance with standard methods found in textbooks. The results obtained from this study indicated that the efficiency of the electrocoagulation process increased by an increase in process time as well as in electric potential difference. The maximum removal efficiency of total coliforms was 100% in potential difference, equal to 30 V in the reaction time of 10 min. Moreover, the results of this study revealed that the electrocoagulation process using a copper electrode was fully able to remove total coliform from poultry slaughterhouse wastewater.

Keywords: electrocoagulation, disinfection, total coliform, wastewater, slaughterhouse, copper electrodes

Introduction

Along with the growth of human society and its needs as well as an increase in rising demand for food and the development of manufacturing industries, pollutants that can bring about short-term and/or long-term problems for humans have been entering the environment [1-3]. Among the above-mentioned industries, the animal protein production industry in the slaughterhouse stage and their creation of a clear risk through discharging their produced wastewater on the environment can be pointed out [4-5]. Poultry slaughterhouses are one of the most important centers for meeting proteins such as meat required for humans [6]. Insufficiencies and deficiencies in slaughterhouses may lower the level of public health. If wastewater resulting from slaughtering associated with high pollution is not treated, it causes serious pollution in the environment [7]. In various stages of slaughtering, large amounts of wastewater containing blood, rumen contents, and materials from washing (equipment and hall) is produced and causes serious pollution of surface water, groundwater, and agricultural lands via discharge into the environment [8]. In addition to slaughterhouse wastewater, several thousand tons of slaughterhouse waste such as bones, offal, etc. are produced by non-industrial slaughterhouses and released around slaughterhouses, which is one of the most important factors for environmental pollutants [9]. On the use of wastewater, microbial guidelines of the United States Environmental Protection Agency (EPA) has determined about 200 and 0 colonies per 100 mL of treated wastewater for restricted and unrestricted urban use, respectively [3, 10]. Also, according to wastewater discharge standards in Iran, the number of fecal coliforms and total coliforms of MPN should be reduced 400 and 1,000 per 100 mL, respectively, in

wastewater, and output wastewater should not have an unpleasant smell and floors and floaters [11]. Due to the high amount of organics in wastewaters, in the case of discharging it in receiving water, oxygen dissolved in the water reduces and reaches zero. These conditions will lead to consequences such as loss of aquatic organisms and creating an unpleasant smell in the receiving waters [12-13].

Pathogenic microorganisms can be pathogenic to humans by discharging slaughterhouse wastewater [14]. Bacteria such as *Salmonella*, *Shigella*, and *Brucella* are likely to be present in slaughterhouse wastewater. Although coliform bacteria in the digestive tract of livestock and poultry are harmless, their presence in water contaminates it and causes the possible presence of other pathogens [15]. The release of contaminants is possible to a very large radius of wastewater discharge [16]. Today's conventional wastewater treatment methods include a variety of physical, biological, and chemical processes such as ion exchange, reverse osmosis [12, 17], biological denitrification [18], adsorption [19-21], and chemical reduction [22-23].

One of the methods in high-pollutant wastewater disinfection is the electrocoagulation process (EC) [7, 24]. EC is an electrochemical process using direct current (DC) to remove contaminants from the solution. In the EC process, coagulant is made up of good materials through electrolytic oxidation of an anode. Then, charged ionic species, heavy metals, or cases other than this are removed through providing ability to react with an ion with opposite electrical charge or metal hydroxides produced in wastewater [9]. In the electrocoagulation process, it is possible to use a different type of electrode. Today some research has noted disinfection capability usage of some electrodes such as copper, which has a microbial property and so far more than 350 copper

alloys are registered with the EPA as solid antimicrobial materials [25]. Considering that copper alloy can kill bacteria continuously without any chemical additives and has no harmful effect on operators in non-digestive contact and low concentrations of it [26], and also due to the extent and frequency of livestock and poultry slaughterhouses, this study was aimed at disinfecting poultry slaughterhouses using the electrocoagulation process with a copper electrode to preserve water resources and realize treatment standards.

Materials and Methods

All chemicals used in this descriptive-analytic study were prepared and used from the Merck Company in Germany (Grade A). Wastewater samples were collected from a depth of 30 cm of output wastewater from the storage tank of a poultry slaughterhouse in Ghaen, Iran, after homogenizing the wastewater at the end of the daily work shift. The samples were kept at a temperature of 4°C and transported to the laboratory in less than one hour. Then the physical and chemical properties of the samples were analyzed [27]. For doing the electrocoagulation process, they were non-continuously transferred into a cubic rectangular made up of an unbreakable glass and resistant to acid corrosion (buccal) with dimensions of 12 × 12 × 16 cm (length × width × depth) and an effective volume of 2 L equipped with 6 electrodes made of iron and copper (75% purity) within just a connection to a transformer for converting urban electric alternating current (AC) to direct DC. The electrodes were connected to the current by a bipolar method, and the other electrodes were inductively applied. In the following, the process efficiency in the removal of coliform from wastewater was examined at different voltages from 10 to 40 V at normal pH and EC and a constant of slaughterhouse wastewater over 60 min. Grid electrodes (for the better flow of wastewater between two sides of electrodes for the better coagulation of wastewater) with a thickness of 2 mm and area of 280 square centimeters (area of grid electrodes) were used together after making the grid according to the number of holes and their diameter (calculated using caliper and fixed distance of 2 cm). Sampling of wastewater was performed once every 15 min through power outage using a damp cotton swab. The samples were plated and counted in TSA and blood agar cultures using the pour plate method. All tests were repeated three times. Finally, the data were analyzed using descriptive statistics parameters and Microsoft Excel software.

Results and Discussion

In recent years, the use of advanced oxidation processes has been an effective alternative for chemical and physical methods of wastewater treatment and the electrocoagulation process is one of them [14].

The physical and chemical properties of poultry slaughterhouse wastewater in Ghaen, Iran were pH 7.95±0.5, electrical conductivity 49.87±8.2 mS/cm, COD 3810.48±15.44 mg/L, BOD₅ 1966.13±67.30 mg/L, TKN 203.7±98.94 mg/L, TSS 946.45±66.09 mg/L, phosphorous 46.1±29.61 mg/L, total coliform 110,000±0.00 CFU/100mL, and temperature 26.2±3.88°C.

Temperature changes: Fig. 1a) shows the mean temperature changes of water environment within electrocoagulation process. Fig. 1a) indicates that the temperature of water environment has increased about 7° under the electrocoagulation process after it had the same temperature with the laboratory environment and reached a maximum temperature of 34°. Many studies have reported similar results [28-29]. It seems that enhancing the temperature is one of the bacterial elimination factors. The reaction temperature affects the physical and chemical properties of the solute, such as viscosity and vapor pressure. This viscosity reduction enhances the process efficiency due to the pole potential difference [30].

pHs changes: Fig. 1b) shows the mean pH changes during the electrocoagulation process in a reaction time of 60 min. Fig. 1b) indicates that pH has increased about three units during the electrocoagulation process and reached from 5.7 to 8.45 at the onset of the process after 60 min. The coagulation process is largely dependent on pH [31], which can potentially be effective in the sequestration of coagulants and the size of coagulant particles [29, 32]. The coagulation process can be a competitor between hydrogen ions and products from metal electrolysis in reaction to organic matter in low pH and a competitor between hydroxide ions and organic anions in reaction with metal ions in higher pH values and prevent the optimal efficiency of the process [29]. pH increase during the electrocoagulation process is due to the production of OH⁻ ions at the cathode reactions [9]. The increase of pH of the process environment improves the performance of electrocoagulation process and increases the removal of pollutants because the efficiency of the iron coagulant acts better in neutral and slightly alkaline environments, especially for pH in the range of 6 to 9 [14]. Also, given the pourbaix diagram (E-pH) for copper, in the process of electric dissolution, Cu²⁺ ions are soluble only at pH less than 7 and with increasing the concentration of Cu²⁺ ions, an area of pH in which the ion is soluble becomes narrow. At pH above 7, CU²⁺ is insoluble and CUO_(s) is obtained from the dehydration of Cu (OH)_{2(s)} [29].

Effects of Time and Potential Changes

Fig. 1c) shows the efficiency of the electrocoagulation process for the removal of total coliform bacteria from poultry slaughterhouse wastewater in reaction times and different potential differences. Fig. 1c) indicates that in the electrocoagulation process using copper electrodes, by increasing reaction time and electric potential difference, the removal efficiency of total coliforms has increased.

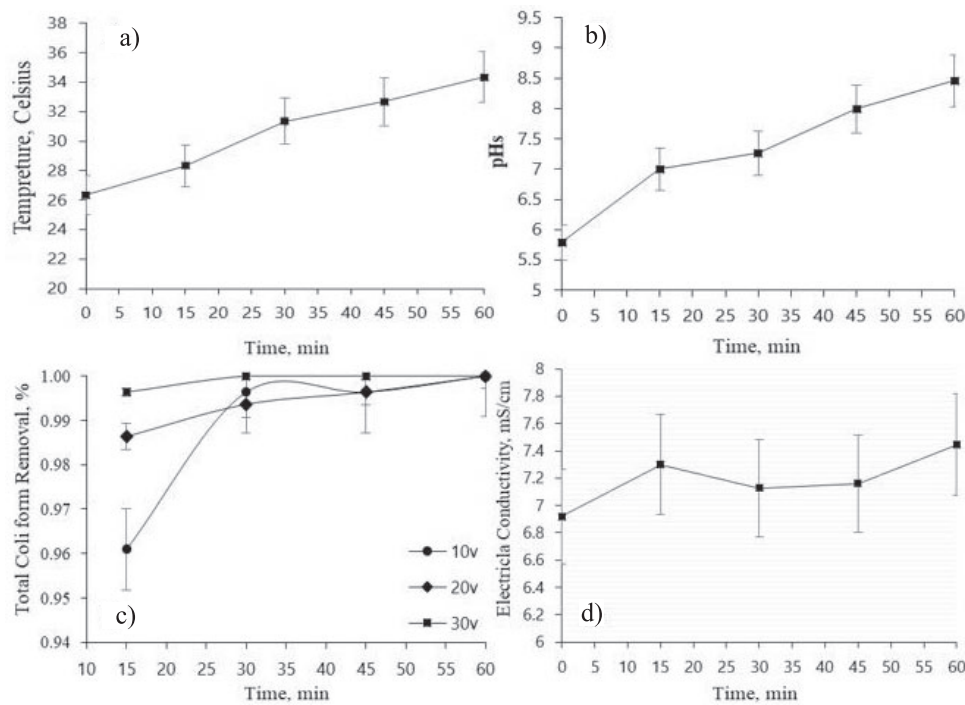


Fig. 1. Disinfection at different times and potential c), temperature changes a), pH changes b), and electrical conductivity changes d).

The maximum removal efficiency of total coliforms has been obtained equal to 100% in the potential difference equal to 30 V and at 60 min response duration. Three major processes including forming coagulants in the aqueous phase, absorbing soluble or colloidal pollutants on the coagulants, and removing bacteria by settling or flotation in the electrocoagulation process are the main causes of disinfecting wastewater samples during the electrolytic reaction at the electrodes [28]. In addition, the efficiency of the process depends on the amount of free copper ions produced in the solution as well [33]. In this study at optimum condition 0.29 kW/h and 1.81 and 0.79 Kg iron and copper per cubic meter wastewater were consumed, respectively. On the other hand, since the amount of produced copper ions is associated with reaction time, by increasing reaction time, the production of coagulants is enhanced and removal efficiency has been improved [29]. According to Faraday's law, it has also been reported that the amount of passing charge from solution is directly related to producing the amount of dissolved iron [32]. Electric potential difference not only determines the amount of coagulant generated in the solution, but also enhances the treatment efficiency in the electrocoagulation process through facilitating the production of bubbles and improving the size and growth of coagulant 'flocks' [31, 34]. In addition, some studies have reported that by increasing current, the size of the bubbles is reduced which leads to quicker and more removal of pollutants.

Increasing the voltage enhances shear force on the electrode surface and the production of coagulant and disinfectant (copper solution) in electrochemical processes [35]. In a study by Rahmani et al. [35], similar

results on the effect of voltage variations on the removal of coliforms in drinking water have been reported. In some other studies, it has also been reported that during an electrochemical process, OH^- and Cl^- ions and other products are factors for wastewater disinfection [36]. In their study, Massoudinejad et al. reported that by increasing the electrolysis time of water for 30 min, the removal efficiency of bacteria increased by about 5% [37]. In the study entitled the removal of material from industrial wastewater using the electrocoagulation process equipped with a copper electrode, Barrera-Díaz et al. reported that using a copper electrode is highly efficient in removing organic matter and that copper has been completely disinfected at a concentration of 4 ppm [29]. It seems that according to the antimicrobial properties of copper, using its electrode in the electrolysis process improves the efficiency of the process for certain removal of bacteria in the coliform group from wastewater.

Electrical Conductivity Changes

Fig. 1d) shows electrical conductivity changes in the environment under the electrocoagulation process over 60 min., and indicates that electrical conductivity has increased by about 0.5 ms/cm. Some studies have reported that by increasing the concentration of electrolyte in electrocoagulation process, the removal efficiency of contaminant becomes more as well because of the direct effect of electrolyte concentration on the electrical conductivity of the solution [33, 37]. In constant current, with increasing the concentration of electrolyte the voltage decreases. By increasing the electrical

conductivity of the solution, anodic dissolution increases and results in an increase in the rate of coagulant in the solution [34].

Conclusions

In this study, the poultry slaughterhouse wastewater disinfection process was evaluated using the electrocoagulation process equipped with the copper electrodes. The results indicated that by increasing the reaction time and electric potential difference, total coliform bacteria removal efficiency has increased in the way that after 60 min, at the potential difference of 10 volts and after 30 minutes at the potential difference of 30 volts, the bacteria in the wastewater were completely destroyed and had no regrowth. Also, at optimum conditions 0.29 kW/h and 1.81 and 0.79 kg iron and copper per cubic meter wastewater were consumed, respectively. Meanwhile, the pH of the wastewater, which was acidic at first, improved to the neutral range and made the discharge of wastewater quite desirable in terms of pH standard after 30 min.

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Ethical Clearance

Taken from the ethical committee of Yasuj University of Medical Science with grant numbers of 92/75 by the Student Research Committee.

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