Removal of culturable bacteria from municipal wastewater using electrocoagulation

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Abstract. Many countries around the world are faced with a serious event that is the pollution of water and wastewater with biological pollutions. This is particularly true in developing nations because of the weak treatment and disposal practice of wastewater. The weak economic situation and low financial support in many low-income countries significantly reduce the development and the uses of innovative water and wastewater treatment methods. This has led to increases and enlarges the issue of water pollution biological pollutants. The goal of this research is to implement the electrocoagulation technique as a cheap and cost-effective technology to eliminate or reduce the per cent of biological pollutant from wastewater. The coagulants are produced in situ by passing a current between two electrodes. A sample of the wastewater was collected from the Kerbala sewage treatment plant, which is located in the southeast of Kerbala city, Iraq. Iron electrodes were used to produce the coagulants in this research study. Besides, the impact of several variables on the performance of the electrocoagulation unit was investigated including the spacing between electrodes and current density. The results revealed that the E. coli bacteria as biological indicator were destroyed after 40 minutes of treatment using iron electrodes with a spacing of 5mm and a current density of 2 mA/cm². Besides, the outcome showed that an initial pH level of 6.0 is suitable for biological pollutants treatment using electrocoagulation.

Keywords: Electrocoagulation, E. coli, wastewater.

1. Introduction
There is an agreement among researchers around the world that the earth is currently faced with serious and grave water scarcity [1, 2]. Researchers attributed the shortage in water resources to many factors. This includes the limited quantity of fresh water on the earth surfaces which is accessible by a human. researchers reported that only 1% of the water found in the plant each is fresh and consumable by human and other livings[2-4]. Besides, the disposal of large quantities of wastewater to surface water bodies, particularly freshwater bodies largely reduced the quality and quantity of freshwater around the world [5-7]. Additionally, the change in the plant earth climate is also reported as important aspects that affect the quantity of freshwater around the world [8, 9]. For example, due to the drought which happens in many parts of the world, the consumption rate of freshwater is significantly increased[2, 5, 10-13].
Besides, climate change influences the natural distribution of water around the world and increases the deficiency of potable water[14-16]. The disposal of wastewater such as industrial and municipal wastewater largely reduced the presence of freshwater around the world [8, 9, 12]. The disposal of wastewater to water bodies is considered as one of the main concerns to water researchers due to the huge quantities of wastewater disposal to water bodies and the diverse types of pollutants found in the wastewater which ends up in freshwater stream [17, 18]. For example, water bodies in many parts around China are significantly polluted with pesticides as more than 300 million tons of pesticides are used in agricultural activities per year which ends up in water bodies [19-22]. In addition to pesticides, many other pollutants can find their way to water bodies like heavy metals, dyes, and organic pollutants [23-26]. The concentration of such pollutants largely increased in water bodies over the last few decades owing to industrialisation and urbanization [10, 27-30]. Researchers showed that the concentration of phosphorus pollutants in river and other water bodies has raised by more than 70% over the last two decades [17, 31-33]. Biological pollutants are considered the main freshwater pollutants and have significant attention among researchers because of their effect on health and the environment [34-38].

The focus on biological contaminants has intensely raised over the last decades [2, 18, 37]. Since the 1850s, scholars start to explore and expand our understanding of the occurrence and the spread of various type of pathogens, particularly through water bodies. Researchers focused on dangerous diseases like gastrointestinal disorders and their spread through water[4, 6]. Despite these efforts to understand the spread of biological pollution, biological pollution is still noticeably increasing because of many aspects like urbanization. Researchers found the more than 30 wells distributed in a rural area in Bangladesh were contaminated with E. coli [10, 12, 30]. This problem is amplified by the lack or the weakness of the advanced treatment method, particularly in poor and developing countries [34, 39]. Accordingly, many pieces of research have been conducted to reduce biological contamination using cheap and effective treatment technologies like chlorination and coagulation [1, 39-42]. Nevertheless, the chemical methods generate various types of by-products that have a toxic impact and reduces their usages in wastewater treatment.

This research is developed with the goal of using an iron-based electrocoagulation unit to remove or eliminate the biological pollution of wastewater. The influences of electrical current density and electrodes spacing on the performance of the iron-based electrocoagulation unit have been investigated to achieve higher removal efficiency of E. coli. The low cost, simple operation, possible development and low sludge production were the main aspects that motivate the author to select the electrocoagulation method for biological treatment[16, 21]. This significantly reduces the need for sludge treatment and final disposal in landfill sites [43, 44].

2. Methodology

2.1. Iron-based electrocoagulation unit

The coagulation unit used in this research is developed for several materials. The electrocoagulation is a rectangular vessel that has 120 mm length, 84 mm depth and 114 mm long and built from transparent plastic. The size and the dimension of the electrocoagulation reactor are based on previous research studies that employed the electrocoagulation method for wastewater treatment [4, 33]. The achieve proper water mixing and improved water treatment 8 iron electrodes. The iron electrodes were laid in a way that enables the water to be mixed while flow through the unit. Each used electrode has a dimension of 96 mm length and 72 mm depth and placed vertically in the electrocoagulation unit. Iron has been selected to be used as electrodes materials in this research because it is cheaply available around the world compared to other materials [45-47]. Besides, the dimension and the placement of the electrodes in the reactor were adopted based on previous research studies [4].

2.2. Wastewater sample
Actual wastewater samples were used in this research to achieve the goal of this research project of disinfecting the wastewater using the electrocoagulation method. The wastewater samples were obtained from the Kerbala sewage treatment plant, which is located in the southeast of Kerbala city, Iraq. The obtained samples were concentrated and diluted with denoised water before conducting the tests. To test the performance of the electrocoagulation method in terms of wastewater disinfection, the E. coli bacteria were used as the indicator. The American Public Health Association method was adopted to conduct the planting and the growth of the E. coli bacteria. The diluted water was planted to determine the number of E.coli colonies and compared with the number of E.coli colonies found in treated wastewater.

2.3. Wastewater disinfection calculations
To calculate the removal efficiency of the electrocoagulation unit, it is very important to find the original number of the E. coli colonies in the wastewater. In this research, the original number of the E. coli colonies in the wastewater is denoted with A1. Then, 600 mL of the wastewater was treated using iron electrodes in an electrocoagulation reactor. The current density and the spacing of the electrodes were changed to achieve the highest disinfection performance. The current densities used in this research 1, 2, and 3 mA/cm\(^2\) and the spacing of the electrodes ranged from 5 to 10 mm. It is worth mentioning that the pH level of the wastewater samples was kept at 6 as the normal pH level of the municipal wastewater is 6 [6, 33, 38]. After each disinfection trial, a sample obtained from the disinfected wastewater were planted and incubated to calculate the residual number of the E. coli colonies (A2). The following formula was used to calculate the removal efficiency of the electrocoagulation unit:

\[
R\% = \frac{A1-A2}{A2} \times 100
\]  

3. Results

3.1. Effects of current density change
Many researchers showed that the current density is considered a very important element in water and wastewater treatment [9, 38]. The current density controls the generation of the oxides from the electrodes which significantly affects the removal efficiency of the contaminants from the wastewater. Besides, the current density also controls the generation of the bubbles that help to float contaminants to the surface of the wastewater [4, 48]. Thus, the effects of the current density on the removal efficiency of the biological pollutants from actual wastewater have been examined. The current density was changed from 1 to 3 mA/cm\(^2\) and the other variables were maintained constants. The pH, treatment time, and electrodes spacing were maintained at 6, 40 minutes, and 5 mm, respectively. Figure 1 presents the results of the effect of changing the current density on the removal efficiency of the biological pollutants from wastewater. The removal efficiency of the E. coli raised from 75% at 1 mA/cm\(^2\) to 100% at 3 mA/cm\(^2\). This can be attributed to the increase in the production of oxides and the generation bobbles with the increased current density. However, the increase in the current density largely affects the treatment cost making the treatment method uneconomical.
The effects of current density on the removal efficiency of the biological pollutants from wastewater.

Figure 2 presents the effects of the current density of the power usage. The figure showed that the increases in the current density significantly increases the power usage which reduces the economic integrity of the electrocoagulation unit using iron electrodes. The power usages significantly raised from 0.8 kW.h/m$^3$ to 7.3 kW.h/m$^3$ when the current density increased from 1 to 3 mA/cm$^2$. Based on the above, it can be said that a current density of 2 mA/cm$^2$ provides high removal and significantly lower cost comparing to 3 mA/cm$^2$.

Figure 2: The effects of the current density of power usage.

3.2. Effects of spacing on the removal efficiency

Studies on electrocoagulation usage in water and wastewater treatment showed that the spacing between electrodes has a large effect on the performance of the method [4, 28]. The spacing between electrodes affects the electrical resistance as smaller spacings have smaller electrical resistance [34, 48].
Accordingly, this could affect the removal efficiency of the electrocoagulation unit. Based on the above, the influence of the spacing between the electrodes has been examined in this research. The experimental parameters that are current density, treatment time and pH level were kept constant at 2 mA/cm², 40 and 6.0, respectively. The spacing between the electrodes was changed from 5 to 10 mm. Figure 3 presents the effect of spacing on the removal efficiency of *E. coli* from the wastewater. It can be seen the larger spacing between the electrodes the lower removal efficiency. From the figure, we can see that the removal efficiency increased from 89% to 99% when the spacing decreased from 10 to 5 mm. The electrical resistance increased with the increase in the spacing between the electrodes which leads to a change in the removal efficiency of the *E. coli* [5, 14, 47].

![Graph](image)

**Figure 3:** The effect of electrode spacing on the removal efficiency of the biological pollutants from wastewater.

### 4. Conclusion

This study examines the application of the electrocoagulation method as a disinfectant for wastewater treatment plant effluent using iron electrodes with different spacing and current density. The outcome of this research revealed that the iron can be used as an electrode in the electrocoagulation method to eliminate the presence of culturable bacteria in wastewater treatment plant effluent. The required time to remove the culturable bacteria from the wastewater effluent was 40 minutes. Based on the results, it can be concluded that the current density and the spacing between electrodes influence the removal efficiency of the culturable bacteria in wastewater treatment plant effluent.

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