Engineered electrocoagulation reactor for the removal of *E. coli* from wastewaters

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**Abstract.** As a consequence of natural pollution, water and sewage are polluted in many nations across the globe. Especially in poorer countries, sewage treatment and disposal practices are often substandard. Throughout many limited-income nations, the poor economic condition and absence of resources assistance severely hamper the planning and application of novel water and sewage systems. This has resulted in a rise in the number of bio-contaminants in the environment. The objective of this study is to use electrocoagulation as a low-cost method to remove or lower the amount of bio contaminant in sewage. By transmitting a voltage between the two conductors, disinfectants are generated in place. Sewage samples were obtained at the Kerbala wastewater treatment plant, which is situated south of Kerbala, Iraq. In this work, steel plates were utilized to create coagulants. Furthermore, the effect of many factors on the performance of the electrolysis device was studied, namely spacing among electrodes and current density. The analysis indicates after 40 min of irradiation employing electrodes spaced 5mm apart and a current intensity of 2 mA/cm\(^2\), the *E. coli* bacteria as a biocontrol agent were killed. Furthermore, the results demonstrated that an initial pH value of 6.0 is appropriate for bio-contaminants removal utilizing electrocoagulation.

**Keywords:** Electrocoagulation, *E. coli*, wastewater, low-cost.

1. **Introduction**

Scientists worldwide believe that the planet is presently facing severe and catastrophic water shortages that represent a real threat to the existence of human beings [1, 2]. Scientists have identified many variables that contribute to the scarcity of water supplies, including the continuous global warming (especially the increase in temperature) [3, 4], increase in the population [5, 6] and the uneven distribution of rains [7, 8]. Moreover, other factors, such as the increase in the urban areas (urbanization) to accommodate the increase in the population, resulted in an increase in the generation of wastewater [9-11], and also in the generation of landfilling process that intern pollutes the groundwater [12-14]. The industry plays a serious role in the shortage of water and pollution of the small amount of fresh
water on the planet’s crust that is available to humans due to the discharging of huge volumes of polluted effluents into the surface water and groundwater [15-17], for instance, cement industry not only discharges polluted wastewater into the environment [18-20] that contain high concentrations of metals [21, 22], dyes [23, 24], organic matter [25, 26], nutrients [27-29] and other pollutants [30-32] but also pollutes the air that intern pollutes surface water [33, 34]. According to the experts, just 1% of the water contained in the planet is fresh and edible by humans and other organisms [35]. Moreover, the dumping of huge amounts of sewage to surface waterways, especially freshwater bodies, has significantly decreased the amount and quality of water globally [36, 37]. Furthermore, changes in the planet climate are cited as major factors influencing the availability of water across the planet [38-40]. For instance, as a result of the dryness that is affecting many regions, freshwater consumption has grown substantially. Furthermore, global warming affects the natural distribution of water across the planet, resulting in a greater scarcity of drinkable water [3]. Although the scientists developed many solutions, such as the development of new treatment methods [41, 42], the development of recycling options to minimise the volume of the industrial by-products [43-45], and the development of eco-friendly alternatives for the traditional industrial products [46-48], water pollution problem still represents the hardest chalenge for scientists [49, 50].

The dumping of sewage, like industrial and municipal sewage, has significantly diminished the availability of freshwater globally [12, 51]. The discharge of sewage to water sources is regarded as among the most pressing problems among water researchers owing to the large amounts of sewage disposed of to waterways and the many sorts of contaminants present in sewage that wound up in freshwater streams. Surface waters in many regions of China, for instance, are heavily contaminated with insecticides since more than 300 million tonnes of insecticides are being used in agricultural operations annually, with the majority of them ending up in rivers and lakes. Aside from insecticides, numerous other contaminants, such as toxic substances, pigments, and organic compounds, can make their way into waterways [52]. The quantity of such contaminants in waterways has risen dramatically in recent decades as a result of industrialization and urbanization. Scientists determined that the percentage of phosphate pollution in rivers and other bodies of freshwater has increased by over 70% in a previous couple of decades [53, 54]. Bio contaminants are the most common waterway contaminants, and their quality of life and the ecosystem has aroused the interest of academics [55, 56].

Microbial pollutants have received a lot of attention in recent years. Scientists began to investigate and increase our understanding of the incidence and transmission of many types of diseases, notably via waterways, in the 1850s. Studies concentrate on hazardous illnesses such as digestive ailments and their transmission via waterways. Although these attempts to understand the spreading of bio-contamination, bio-contamination is still on the rise due to various factors such as urbanization. For example, according to scientists, over 30 reservoirs in a rural part of Bangladesh were discovered to be polluted with E. coli. This issue is exacerbated by a lack of or inadequacy in modern treatment methods, especially in underdeveloped and developing nations. As a result, several studies have been undertaken to decrease biological contamination through the use of low-cost and efficient treatment methods such as disinfection and coagulation. Nonetheless, chemical techniques produce a variety of by-products that have a damaging effect, limiting their use in sewage treatment.

This project aims to use a steel electrocoagulation device to reduce or eradicate contamination from sewage. To obtain a better E. coli extraction efficiency, the effects of electrical charge intensity and electrodes separation on the operation of the steel electrocoagulation device were examined. The author chose the electrocoagulation technique for biotreatment because of its low price, convenient implementation, potential improvement, and minimal waste generation [57, 58]. This eliminates the necessity of sludge treatment and eventual disposal in dumps.

2. Research Methods

2.1. Electrocoagulation device
The device utilized in this study was designed for a variety of substances. The electrocoagulation vessel is a rectangle made of clear plastic with dimensions of 130 mm length, 90 mm depth, and 120 mm width. The electrocoagulation reactor vessel size and dimensions are based on prior investigations that used the electrocoagulation technique for sewage treatment. Eight steel electrodes are used to ensure appropriate water mixture and better sewage treatment. The steel electrodes were constructed in such a way that the water could be stirred as it passed via the device. Each utilized electrode is 110 mm long and 81 mm deep, and it is positioned vertically in the electrocoagulation device. Steel was chosen for use as electrode material in this study since it is relatively inexpensive when compared to other options. Furthermore, the dimensions and location of the electrodes in the device were determined using prior scientific literature.

2.2. Sewer water samples

Real wastewater samples have been utilized in this study to meet the objective of sterilizing sewage utilizing the electrocoagulation technique. The sewage specimens were taken from the Kerbala wastewater treatment facility, which is situated south of Kerbala, Iraq. Before performing the tests, the collected samples were diluted with denoised water. The E. coli organisms were employed as an indication to assess the efficacy of the electrocoagulation technique in terms of sewer water disinfection. To perform the seeding and development of the E. coli bacterium, the American Public Health Association technique was used. The count of E. coli colonies identified in the water samples was contrasted to the number of E. coli colonies found in the treated sewer water.

It is critical to determine the initial amount of E. coli colonies in the sewage before calculating the removal effectiveness of the electrocoagulation device. The initial number of E. coli colonies in the sewage is designated by J1 in this study. The effluent was then processed in an electrocoagulation device with iron electrodes. To obtain the best sanitation efficiency, the current and the spacing were varied. The current densities utilized in this study were 2, 4, and 6 mA/cm², with electrodes separation ranging from 10 to 30 mm. It is important to note that the pH level of the sewage water is maintained at 6, as this is the usual pH level of greywater. Following each treatment attempt, a specimen of sterilized sewage was seeded and cultured to determine the remaining numbers of E. coli colonies. The reduction effect of the electrocoagulation device was calculated as follows [23]:

\[
\text{Removal} \% = \frac{J_1 - J_2}{J_2} \times 100
\]

\(J_1\) and \(J_2\) represent the numbers of E. coli colonies before and after the electrocoagulation process per water sample.

3. Outcomes

3.1. Current density

Several studies have shown that power density is a critical factor in water purification. The current regulates the production of compounds from the poles, which has a major impact on the extraction efficiency of wastewaters. Furthermore, the current governs the formation of bubbles, which aid in the movement of pollutants to the sewer water top. The impacts of power density on the removal effectiveness of bio-contaminants from greywater have therefore been investigated. The current was increased from 2 to 6 mA/cm², while all other parameters remained unchanged. The acidity, treatment duration, and electrodes separation were all kept constant at 6, 50, and 10mm, correspondingly. The findings of the impact of altering the current intensity on the extraction efficiency of bio-contaminants from sewage are shown in Figure 1. The E. coli elimination effectiveness increased from 68% at 2 mA/cm² to 84% at 6 mA/cm². This could be due to an increase in the oxidation process and generating bubbles as power density increases. Nevertheless, an increase in current density has a significant impact on treatment costs, rendering the treatment technique impractical.
Figure 1: The influence of the current on the effectiveness of bio-contaminant extraction.

Figure 2 shows the impacts of energy use current density. The graph shown that increasing the current density considerably increases power consumption, improving the financial integrity of the electrocoagulation device utilizing steel electrodes. Whenever the current density rose from 1 to 3 mA/cm², the power consumption increased considerably from 1.6 kW.h/m³ to 14.2 kW.h/m³. According to the foregoing, a current of 4 mA/cm² offers superior elimination at a much cheaper price than 6 mA/cm².

Figure 2: The impact of current density on power consumption.

3.2. Electrodes spacing

According to research on the use of electrolysis in water purification, the distance among poles has a significant impact on the technique’s effectiveness. The resistivity is affected by the distance between electrodes, with shorter distances having lower resistivity. As a result, the electrocoagulation unit’s
removal rate may suffer greatly. Depending on the foregoing, the effect of electrode spacing has indeed been investigated in the present study. The Current, duration of treatment and acidity level was held constant at 4 mA/cm², 50, and 6.0, accordingly. The electrodes spacing was increased from 10 to 30 mm. Figure 3 depicts the influence of distance on E. coli removal effectiveness from sewage. As could be observed, the longer the distance between poles, the lesser the maximum removal. The figure illustrates that whenever the gap was reduced from 30 to 10 mm, the removal effectiveness rose from 75 to 86 percent. The resistivity rose as the distance between the electrodes grew, resulting in a shift in the E. coli elimination effectiveness.

Figure 3: The influence of spacing on the effectiveness of bio contaminant removal.

The authors of the present work recommend investigating the recent sensing technologies; examples of these technologies is the electro-magnetic sensors [59-61] and sonic sensors [62-64], in water treatment (in the electrocoagulation plants) to achieve an efficient monitoring process for the removal of pollutants.

4. Conclusion
The applicability of the electrocoagulation technique as a sterilizer for sewage treatment plant discharge utilizing steel plates with varying separation and current is explored in this research. This study found that steel may be utilized as an electrode in the electrocoagulation technique to remove the existence of E. coli microorganisms in sewage treatment plant discharge. It took 50 minutes to eliminate the E. coli germs from the effluents discharged. Based on findings, it is possible to deduce that the power density and plate separation impact the removal effectiveness of E. coli in sewage treatment plant discharge.

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