Fluoride removal using electrocoagulation technique

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Abstract. A modest quantity of fluoride can increase the mineralization of teeth and reduce their cavities. But the presomeration of fluoride in excess in water can lead to severe disease infertility. In the past few decades, scientists have thus been preoccupied with developing ways to reduce sewage fluoride concentrations and reduce their effects on human health. The present study is aimed at using the technology of electrocoagulation to remove fluoride from polluted water. Tests have been done to examine the elimination of fluoride with a rectangular electrocoagulation cell and examine the impact of the experimental aspects on fluoride extraction, specifically electrical current, electrode spacing, and pH. The authors found that 93% of the fluoride has been extracted using 5mm spaced electrodes with a current density of 2 mA/cm² and a level of pH of 7 from the polluted water after 20 min of processing. Experimental factors considerably impact the efficacy of fluoride removal. In the acidic environment, greater effectiveness of fluoride removal is being attained. The elimination effectiveness depends directly on the electric current, whereas the distance between poles is adversely linked to fluoride elimination.

1. Introduction
Water is a crucial part of the planet earth’s exit forms of life. Nevertheless, just 1% fewer is fresh and suited for consumption. Suitable amounts of drinking water are regarded as one of humankind’s significant difficulties due to the increasing population [1, 2]. Additionally, authors have proved by the 2050s, half of the worldwide people may have no access to potable water [3]. This trend is subjected to a rapid increase due to the extensive discharge of industrial wastewaters [4, 5] and consumption of fresh water during the production processes [6-8], urbanisation [9-12], global warming [13-15] and air pollution that is in contact with surface water [16-19]. Other researchers have pointed out about 33.6 million barrels of severely contaminated water are released annually into water sources (surfaces or underground) [20] because of rapid industrialization; thus, the situation is much more complex [21]. Fluoride is among the most prevalent elements where it constitutes around 5% of the earth’s surface [22, 23]. Consequently, many watercourses naturally contain fluoride at a low quantity. However, expanding industrialization increased fluoride concentration [24, 25]. For instance, high-temperature chemicals deposit enormous amounts of polluted effluent of fluorides in the manufacturing of the electronics like aluminium and steel [26-28]. The small level of fluoride in water prevents tooth cavitation; nevertheless, large levels can contribute to severe illnesses like skeletal paralysis. Eventually, fluoride levels in drinkable water were restricted to 1.2 mg/l by the World Health Organization [22]. Scholars are now using several processing procedures to eliminate water and wastewater pollutants [29-32]. Electrocoagulation is an appealing treatment method owing to low cost [33-35], flexibility as it can be...
combined with other methods [36-38], produce few sludges [39, 40] and operate using sensors [41-44]. The sludge is full of metal ions which improve the recycling potential of sludge instead of disposal in expensive landfills [45-49]. The electrocoagulation method has been utilized to remove a range of contaminants from the aquatic environment, including toxic substances and microbiological contaminants. For example, this technique was cleaned to reduce arsenic from contaminated water by Fe-Al electrodes, where approximately 100% of arsenic has been eliminated in 0.5 hours [22]. Aluminium electrodes in an acidic environment are also useful for reducing the contamination of other metals like nickel and copper. This method has also been applied in order to eliminate organic contaminants from industrial sewage, with effectiveness of around 85 percent over 45 min [50-52]. Fluoride is also removed from polluted water using electrocoagulation. In artificial industrial effluents employing aluminium electrodes, for example, the fluoride content was reduced. The influence on the wastewater treatment utilizing the electrocoagulation method of many factors, including the current density, and pH have been investigated by several academics [53-55]. The removal of fluoride from drinking water was also achieved via electrocoagulation. The literature utilised this approach to reduce fluoride from artificial drinking water at the starting dose of 2-10 mg/l [22]. The water contamination crisis affects humankind for generations, and safe techniques of treatment of water are necessary for the expected growth in demand for drinking water. Therefore, investigators are now concerned with using safe ways to eliminate water contaminants. Electrocoagulation offers a strong treatment alternative compared to many other standard treatment approaches for water and wastewater because it is cheap, compact, and produces good sludge. Therefore, the project intends to use the electrocoagulation approach to reduce fluoride concentration in wastewater using a perforated plate of aluminium electrodes.

2. Methods

2.1. Chemicals and electrocoagulation unit

All reagents included in this experiment were supplied by Sigma-Aldrich without adjustment or decontamination. The Artificial liquid was created to achieve a 500 mg/l of fluoride level throughout this stock solution by melting a certain quantity of fluoride (NaF) into deionized water based on Hashim et al., [56] method. Dilution has been applied to specimens of 1 liter in size to achieve lower levels of fluoride concentrations. Furthermore, the pH-values for the liquid ranging from 5 to 9 were controlled by HCl and NaOH, and NACl was employed to keep contaminated water conductive at 0.3 mS/cm. In this research, a reactor of 1 liter in size having inner dimensions of 50, 200 and 100 mm for wide, length and height correspondingly was used to remove the fluoride from Artificially polluted water. Inside the reactor, four perforated aluminium sheets were vertically placed on improving liquid circulation and enhancing pollutant removal.

2.2. Methods for experiment

The reactor was filled with 500 ml of polluted water. The reactor input and output were linked to accomplishing the electrolyzing procedure, and a peristaltic pump was used for circulating water. The reactor was connected to reliable electricity. In order to test the acidity, conductivity and temperature of the solution, a pH-meter, conductivity meters and thermometer were employed. In all the experiments, the ambient temperature of 20 ±1 °C was maintained. The removal efficiency was determined after the equation reported by as follow [57]:

\[ E(\%) = \frac{x-x1}{x1} \times 100\% \quad (1) \]

Where x represents the ultimate solution fluoride concentration, whereas x1 is the initial mg/l fluoride concentration, and E is Florida’s removal effectiveness.

2.3. The impact of the test settings
In research, the impact on the efficiency of removal of fluid Ions from the water was examined by 3-parameter that are electric current strength, pH-level and distance among plates [53]. The pH influence was examined in this study by maintaining 2 mA/cm² of electric current, 5 mm of electrodes separate and an initial 10 mg/l fluoride concentration for 20 minutes, while the pH level changed from 5 to 9. The impact of electric current was investigated utilizing 1, 2 and 3 mA/cm² while keeping a pH of 7, spacing of 5mm, fluoride of 10mg/L. Finally, the effect of plate separation was investigated by changes of the plate separation from 5 to 10 with the rest of the parameters maintained.

3. Results and discussions

3.1. pH impact
The pH value has a key role in treating any contaminant [57]. A 600 ml of water samples were treated for 20 minutes using varied pH-values of 5, 7, and 9 with 5 mm distance between electrodes and 2 mA/cm² electrical currents to examine the impact of pH-value on the removing efficiency of fluoride. The effect of pH on fluoride removal effectiveness at different pH values is presented in Figure 1. With a reduction in wastewater acidity, the extraction efficiency of the contaminant improved. Acidic levels achieved the best removal effectiveness. However, the removal effectiveness reduces considerably as the wastewater turns alkaline. The difference in fluoride removal efficiency suggests an alkaline condition is not suitable for fluoride by electrocoagulation. Studies claimed that the preference for better fluoride removal is the acidic environment [58].

![Figure 1: The pH impact on fluoride elimination.](image)

3.2. Electrical current impact
The current significantly affect fluoride removal by controlling bubble sizes and floc formation. In this study, three distinct currents range from 1 mA to 3 mA/cm² with pH at 7, initial pollutant content at 10 mg/l and spacing at 5 mm, were investigated to determine the impact of the currents on the removal. The reduction of fluoride enhanced greater current as shown in figure 2. for current of 1, 2 and 3 mA/cm² after 5 min of operation, the removal effectiveness range amounted to around 65%, 74.3% and 77.1%, correspondingly. This verifies the fact that delivering more energy immediately increases the reaction resulting in coagulation-controlled species and accelerates the generation of the flock to increase the efficiency of removal.
3.3. Spacing impact

Scholars indicated that electrocoagulation removing efficacy is strongly affected by electrode separation. Therefore, 600 ml of polluted water having initial fluoride content of 10 mg/l, pH-level 7 using an electrical current of 2 mA/cm², to study the impact of the electrodes separating on the removal performance. The intervals between electrodes were changed from 5 to 10 mm. The results presented in Figure 3 reveal that the separating distance adversely affects the removal efficiency. The fluoride concentration decreased from 93% to 84% after 20 minutes of treatment when the electrode distance increased from 5 mm to 10 mm. Studies link the electrical impedance between electrodes to the changes in pollutant removal performance [31, 56].

The improvement of the electrocoagulation in terms of fluoride removal, as was noticed in the results, could be achieved via controlling the operating parameters, such as the current density and pH of the water. Such parameters, especially the pH, can be monitored using sensors that provide real-time measurements, such as the ultrasonic sensors that are in use in the concrete industry [59, 60], or microwave sensors that are used in communications [61, 62] and pollution monitoring [63, 64].

4. Conclusion

The present investigation examined the efficacy of the electrocoagulation method using aluminium electrodes and the influence of the major operational elements (pH, electric current, and distance between electrodes) in terms of fluoride removal from polluted synthetic water. It can be claimed that electrocoagulation could be utilized to extract fluoride from polluted water, based on the current results of this experimental investigation. The operational elements also have a strong impact on fluoride
removal efficiency. In removing fluoride, the pH plays a crucial role as a higher removal effectiveness can be obtained in the acid environment. The effectiveness of removal is connected favourably to the electric current as it promotes coagulants formation. The distance between electrodes adversely affects the effectiveness of fluoride removal from polluted water. After 20 minutes, the removal efficiency using 2 mA/cm² and 5 mm gap at a 7 pH level was 93%.

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