Treatment of Saline Water Using Electrocoagulation Process with Monopolar Connection of Electrodes

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ABSTRACT

For the availability of drinking water, saline water treatment has become exceedingly necessary. The purpose of this research was to determine how efficient electrocoagulation (EC) with monopolar iron electrodes was for desalinating water from Iraq's Sawa Lake. Absolute dissolved solids (TDS), chloride (Cl), bromine (Br), and sulfate (SO_4) are some of the salty water forms that are being targeted. The impacts of five considerations on treatment efficiency were studied, including current (I), detention time (RT), pH, speed of mixing stirring (Mrpm), and inter-electrode distance (IED). I=0.8A, RT=80 minutes, pH=8, IED=1cm, and Mrpm=500 were found to be the best values. TDS, Cl, Br and SO_4 removal efficiencies were 91 percent, 93 percent, 92 percent, and 90 percent, respectively, under ideal conditions. It can be inferred that the EC system used in this research was operative in removing salts from the water of Sawa lake.

INTRODUCTION

Freshwater supplies have been depleting in recent years around the world, necessitating water treatment and recycling. Desalination is an effective process to treat the freshwater depletion crisis because seawater accounts for more than 98 percent of all available water on Earth (Hanafiah et al. 2011). The removal of minerals and salts from using water is known as desalination. Distillation of thermal, nano type of filtration, adsorption, reverse osmosis (RO), electrocoagulation, electrodeposition, and electrooxidation are some of the methods that can be used to treat contaminated water (Greenlee et al. 2009). Any of the approaches mentioned, however, have significant flaws. The energy usage and costs of thermal desalination for water desalination at 45 percent recovery are approximately 13 kWh.m^{-3}. Around 40% of the world's water is desalinated by thermal means (Singleton et al. 2011). In the last three decades, RO has dominated technology, especially in energy-rich countries like Saudi Arabia. For desalination of salty water at 40 percent retrieval, RO will operate at a rate of about 3% kWh.m^{-3} (Loow et al. 2015). The disinfectant chlorine added to water will dissolve the polyamide membrane, necessitating a dechlorination step until separation (Cipollina et al. 2009). Furthermore, replacing a membrane is an expensive operation (Pérez-González et al. 2012). The cost of advanced oxidation processes is high

(Elimelech & Phillip 2011). Although adsorption and nanofiltration methods aren't often enough to meet discharge limits (Glater et al. 1994). However, one of the options for water desalination is to use the electrocoagulation (EC) process. Electrocoagulation is the method of using an electric current to destabilize suspended pollutants and molten elements in an aquatic medium. An electrolytic cell consisting of Plexiglas, glass, copper, anode, and cathode are the key components of an EC reactor. Metal plates make up the anode and cathode, with the anode referred to as "sacrificial electrodes." These electrodes are typically constructed with the same or different components, such as iron (Fe) and aluminum (Al). The EC procedure, which uses a simple tool and produces a small amount of sludge, has been successfully used to extract salts from salty water (Mohammad et al. 2015, Martinez-Huitle & Ferro 2006). This approach is distinguished by its safety, simplicity, ease of control, and selectivity, as well as its usability, automation potential, and environmental compatibility. As electrodes are used in the EC procedure, iron dissolves and acts as a coagulant agent, releasing hydrogen gas at the cathode. Different aquatic iron species are produced during iron dissolution at the cathode (Panizza & Cerisola 2011). Former research has shown that the EC system is an important technique for treating various water pollutants such as arsenic, fluoride, boron, and nitrite in textile wastewater, chemical fiber wastewater, algae or microorganisms, oily

wastewater, restaurant wastewater, and sewage water arsenic, fluoride, boron, and nitrite in sewage water (Bousher et al. 1997, Chen 2004, Mollah et al. 2001). Different metal ions, such as Zn, Ag, Cu, Co, and Mn, were removed using the EC method (Naje et al. 2015). The goals of this investigation are to decide on peak settings influencing the removal efficiency of TDS, Cl, Br, and SO_4 from saline water using the electrocoagulation system with static electrodes under monopolar electrical relation, and to assess the efficacy of the electrocoagulation method for saline water treatment.

MATERIALS AND METHODS

Characteristics of Saline Water

Sawa Lake, Iraq, provided the salty water samples. Table 1 summarizes the features of saline water. Sawa Lake is about 240 kilometers southwest of Baghdad, in the AlMuthanna province of southern Iraq, between 31o 18' N and 45o 00' E. (Fig. 1). Since the lake has no artificial water sources, groundwater is the primary source of water. The gross surface area is approximately 10 km², the average depth is 5.5 meters, and the average length and width are 5 and 2 kilometers, respectively. The Iraqi Ministry of Health and Environment published a report in 2020 on the physical-chemical characteristics of saline water at Sawa Lake (Abbas et al. 2020). Among Iraq's inland waters, Sawa Lake is thought to have the highest salinity.

Setup of Experiment

The experimental setup for the EC method used in the current analysis is illustrated in Fig. 2. The treatment of salty water from the Lake of Sawa was carried out in a batch reactor made of glass, with a Plexiglas upper layer. TDS, Cl, SO_4, and Br levels were determined in the salty water. The experiment used a reactor with dimensions of 20 cm width, 15 cm length, and 15 cm depth. For each run, the treatment water volume was 4.5 L. Six iron plates were wired in series with the main power supply, with monopolar link anodes and cathodes. The electrodes for both the anode and cathode plates were 10 * 10 cm² with a thickness of 0.1 cm and a spacing between the inner electrodes of 1 cm. 100 cm² is the surface area of each electrode. The electrodes were submerged in salt water after being collected. The negative and positive terminals of the DC power supply are attached to the anode and cathode groups. The stirring speed was regulated by a magnetic field.

Table 1: Features of saline water.

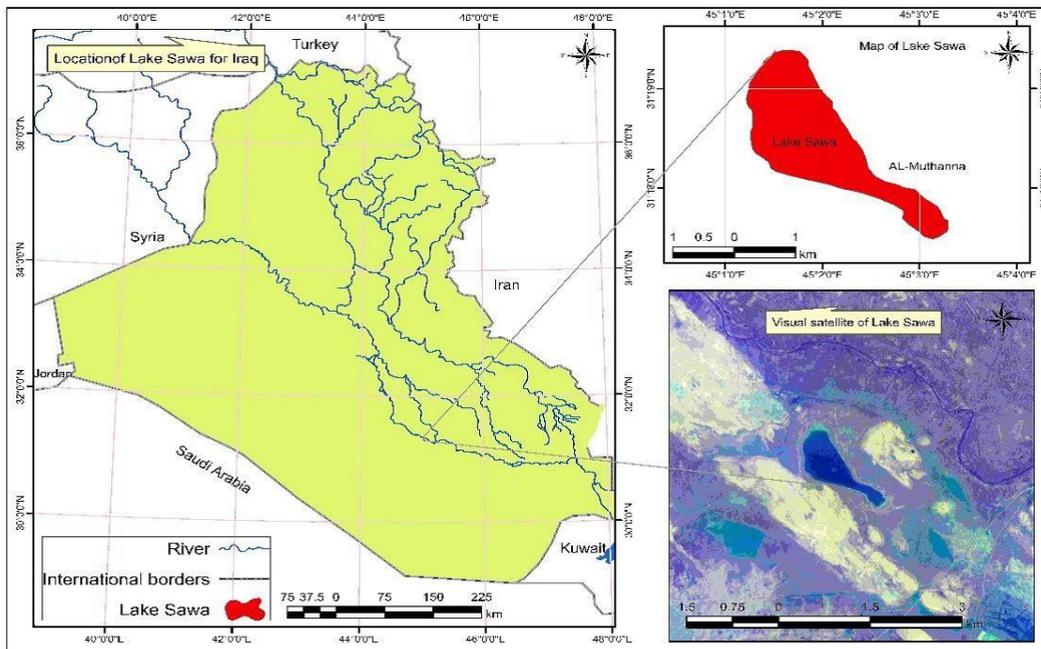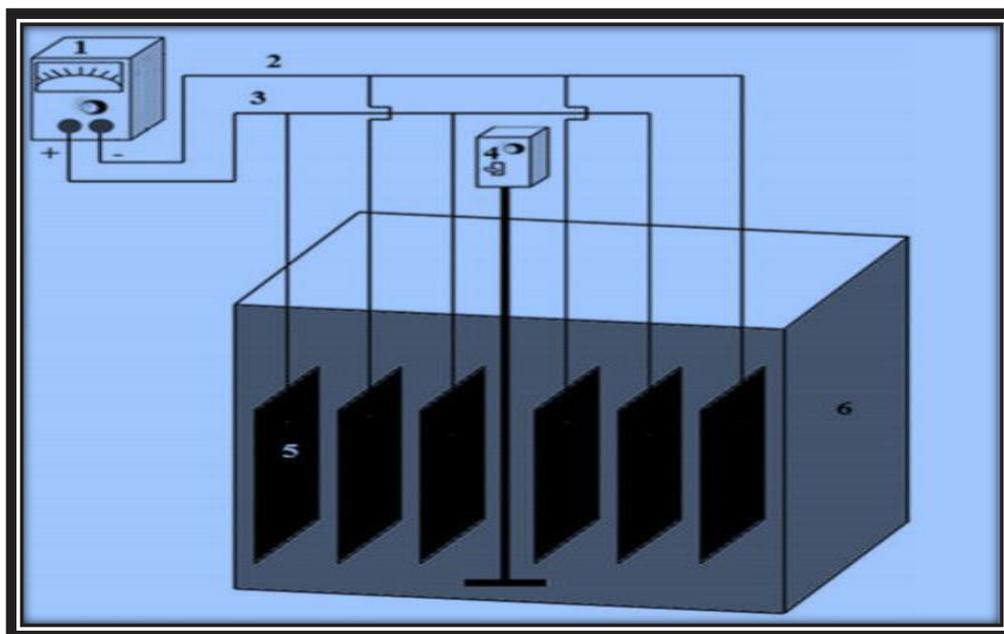| Properties	Values
TDS (mg.L^{-1})	26263
Cl (mg.L^{-1})	8498
SO_4 (mg.L^{-1})	6562
Br (mg.L^{-1})	6.00
pH	8.25

Fig. 1: Lake Sawa (Iraq) on a map.

Fig. 2: Experimental configuration diagram: (1) DC power supply; (2) cathode; (3) anode; (4) mechanical stirrer; (5) iron electrodes; (6) EC reactor

When an electric current was passing through the electrodes, anode and cathode reactions occurred on the surface of the inner electrodes.

A DC power supply made by YIZHAN, 0-40V; 0-6 A, China, was used in the current analysis. During each run, the voltage was set to 15 V, and the influence of current was determined between 0.2 A and 1.2 A for 100 minutes. The criteria for removing TDS, Cl, Br, and SO_4 from lake water are mentioned in Table 2. To ensure the accuracy and durability of the results, all experiments were tested for 92 runs to determine the optimum conditions, which were then replicated three times. A multi-range ammeter produced by Aswar DT830D, China, was used to retain the current standard. The electrodes were thoroughly washed with purified water after each cycle. The tests were carried out in the Laboratory, which was set to a temperature of 25°C. The pH of the feed water and product was determined, and the pH was changed to a range of 5 to 11, after which sodium hydroxide or hydrochloric acid solutions were applied to maintain the pH stable for each experiment.

The Analysis of Factors

Table 3 gives the processes and instruments used to assess saltwater contaminants before and during treatment.

RESULTS AND DISCUSSION

Influence of Useful Current and Passage Time

The useful current and reaction time are two significant parameters in the EC mechanism that play a key role in controlling the reactor rate. At different useful current densities (I = 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2) and reaction times (20, 40, 60, 80, and 100), tests were performed to determine the percentage elimination of TDS, Cl, Br, and SO_4 from saline water. Figs. 3, 4, 5 and 6 demonstrate the influence of applied

Table 2: The criteria that have been looked at for the handling of lake water.

Parameter	Unit	Range	Run	Replicated optimal conditions
Current density	A	0.2-1.2	6	3
Reaction time	min	20-100	5	3
pH solution	-	5-11	8	3
IED	cm	0.5-2	4	3
M_{rpm}	rpm	250-750	3	3

Table 3: The criteria of the study and analysis method.

Parameters	Meter/method
pH	pH meter –pHM84
TDS	TDS meter (TDS-EZ, HM Digital)
Electrical Conductivity	HANNA HI-99301
Turbidity	HACH 2100P
Br^-	Ion chromatography
SO_4^{-2}	APHA, gravimetric
Cl^-	Titration (Mohrs Method)

current (I) and reaction time on removal efficiencies. With increasing reaction time, the performance of the EC process increases. At I = 0.8A and RT = 80 min, the best removal efficiencies can be found. 90 percent TDS, 92 percent Cl^-, 91 percent Br^-, and 88 percent SO_4^{-2} had the highest removal efficiencies. There is a slight, non-significant rise in removal efficiencies after 80 min, increasing energy usage. As a result, the best operating variables were chosen as 0.8 A and 80 min, which are also consistent with the findings of former research (Heidmann & Calmano 2008, Phalakornkule et al. 2010).

Influence of pH

Former studies also highlighted the significance of pH's impact on water treatment in the EC system. The effect of pH on TDS, Cl, Br, and SO_4 elimination was studied in this analysis by changing the initial pH in the range of 5 to 11 with peak settings Fe- Fe, I = 0.8 A and an 80-minute reaction time. Fig. 7 indicates that at pH 8, TDS, Cl, Br, and SO_4 removal efficiencies increased to 91 percent, 93 percent, 92 percent, and 90 percent, respectively. The presence of water electrolysis, which produces hydrogen and (OH) ions, is responsible
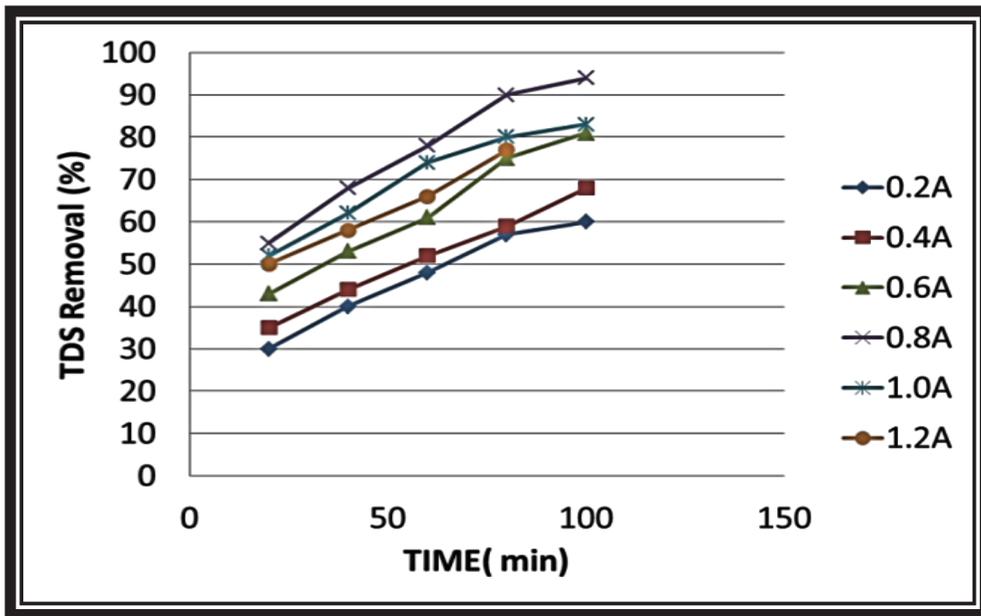

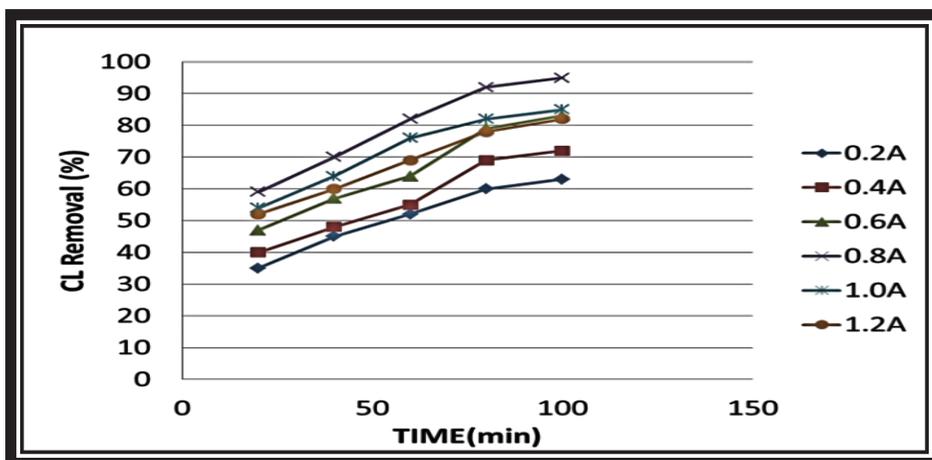Fig. 3: TDS removal performance as a function of useful current.

Fig. 4: Cl removal performance as a function of useful current.

for the rise in pH levels. The formation of insoluble $M(OH)_3$ flocs and metal hydroxide can explain why pH remains relatively stable after that. At pH values of 5 and 6 in the acidic phase, and 9, 10, and 11 in the alkaline phase, the findings indicate decreased levels of solubility in iron hydroxide. The peak pH level observed in the current analysis is consistent with the results of former studies (Phalakornkule et al. 2010, Lin & Peng 1996). Saline water with a pH of 8 is perfect.

Influence of Inter-Electrode Distance

To achieve an appropriate electrode surface area and inter-electrode space, the electrode assemblage set-up is important (IED). If the distance between the two electrodes grows, so does their resistance (Murad et al. 2011). As a consequence, the electrical current levels are decreased. Theoretically, increasing the distance between electrodes leads
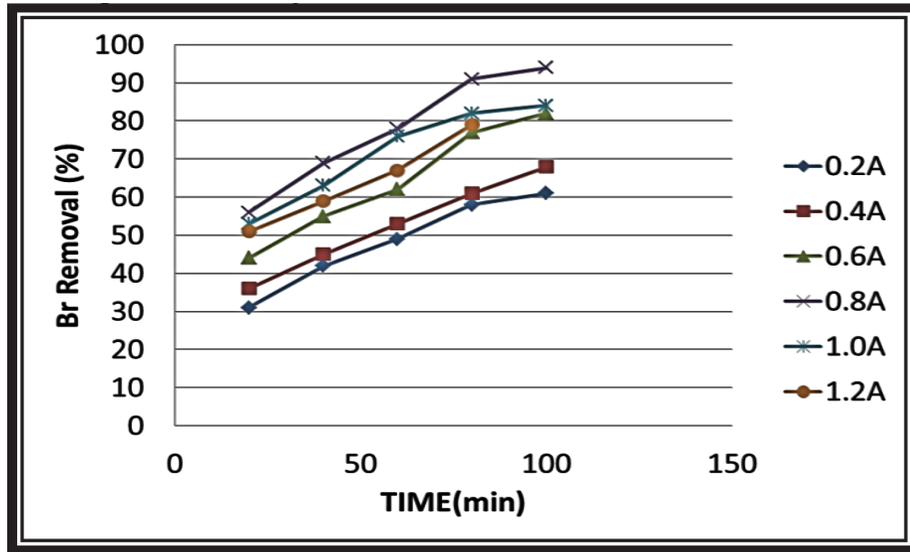

Fig. 5: Br removal performance as a function of useful current.
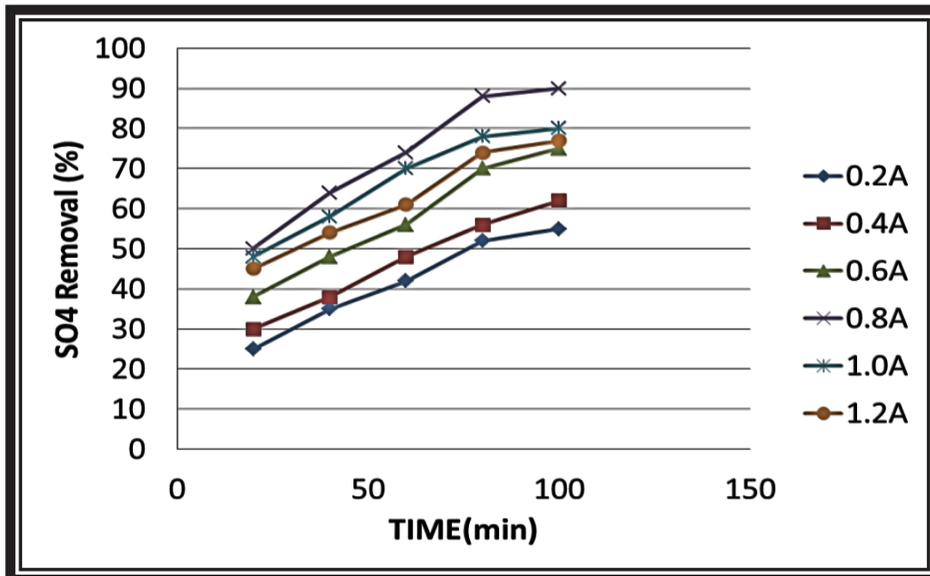

Fig. 6: SO$_4$ removal performance as a function of useful current.

to less contact between ions and hydroxide polymers. The influence of the IED on the EC method's removal efficiency has been shown in former studies. The following equation governs the difference in a voltage drop (IR) (Deverel & Millard 1998, Naje et al. 2015):

$$IR = I \times (d/s \times k) \qquad ...(1)$$

Where I denotes the electric current in Amperes (A), d denotes the distance between the two electrodes in meters, S denotes the active anode surface area in square meters, and k denotes the precise conductivity in Siemens per meter. As the inter-electrode gap (IED) is increased while the anodic surface area and conductivity of the solution remain unchanged, the voltage drop increases. The effect of IED was investigated in the current study using Fe-Fe, I = 0.8A, RT = 80 min, and pH = 8 as peak settings, as seen in Fig. 8. With 1 cm as the middle distance, the best results were obtained. For a change of the gap from 0.5 to 1 cm, the obtained findings were 90 to 91 percent TDS, 92 to 93 percent Cl, 90 to 92 percent Br, and 88 to 90 percent SO_4. Expanding the gap from 1.5 to 2 cm, resulted in lower care efficiencies of 90 to 87 percent for TDS, 91 to 88 percent for Cl, 90 to 87 percent for Br, and 87 to 82 percent for SO_4. Former studies showed that increasing the inter-electrode gap (IED) contributed to
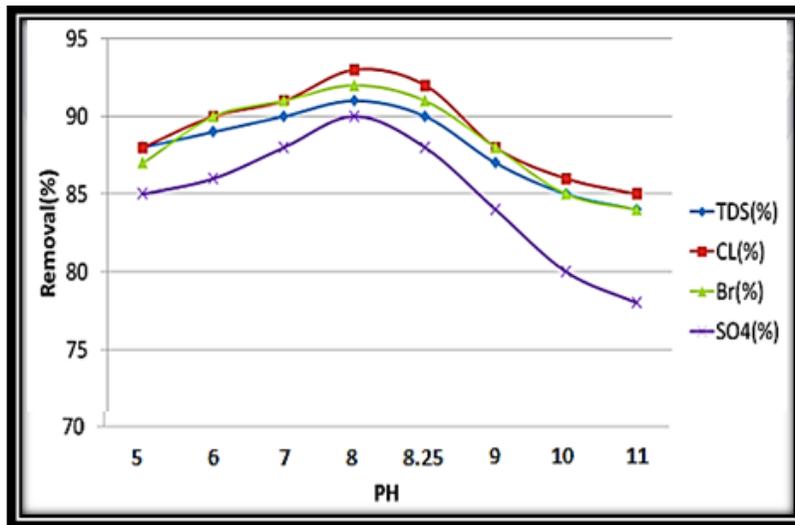

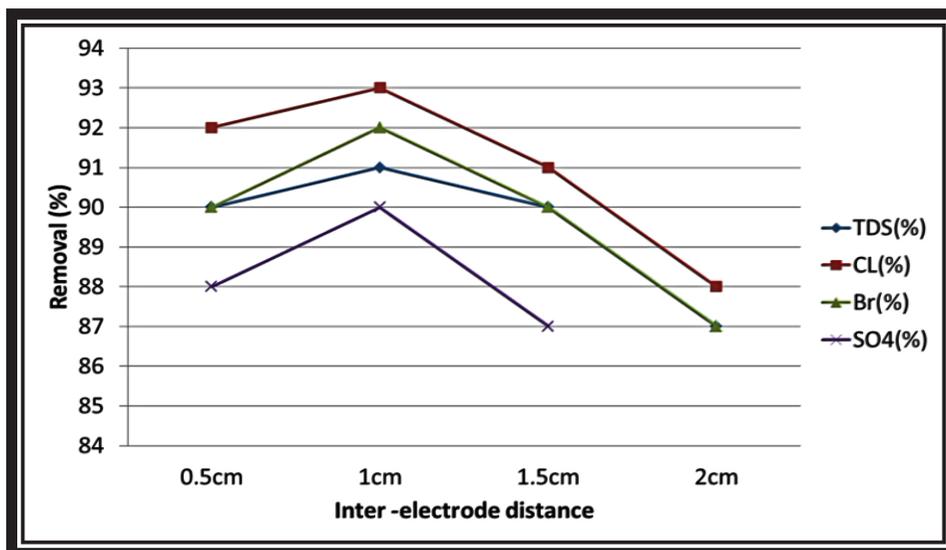Fig. 7: The pH effect at peak settings.

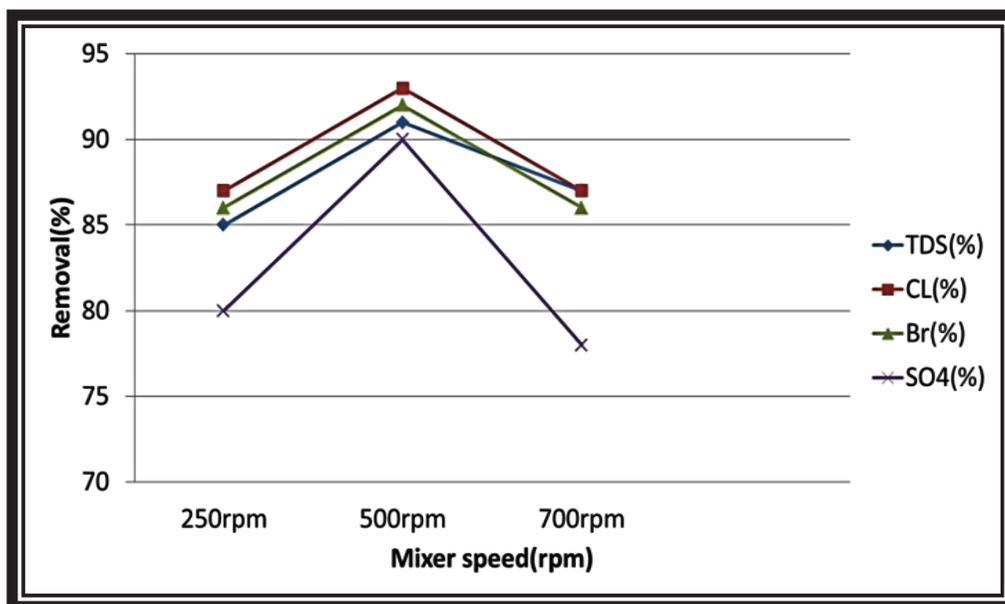Fig. 8: Effect of inter-electrode distance under optimal conditions.

Fig. 9: Influence of mixer speed under peak settings.

a decrease in electrode attraction, which clarified the effect of the final IED on the efficiency of contaminants removal (Aber et al. 2009, Mollah et al. 2004). This was discovered in the iron polymers made, which has a negative impact on the treatment.

Influence of Stirring Speed

The EC method is influenced by the mixing stirring speed (Mrpm). As the stirring rate is increased, emission forms, which is monopolar and connected, making precipitation and mass transfer simpler. As the stirring rate is increased above what is needed, the pollutants that develop inside the reactor degrade, resulting in smaller flocks that are difficult to isolate from the solution (Hamdan & El-Naas 2014, Korbahti & Tanyolac 2009). Treatment reliability suffers as a result of this behavior. Stirring speeds of 250, 500, and 750 rpm were used with peak settings of Fe-Fe, I = 0.8 A, RT = 80 min, and pH = 8 to investigate the effect of agitation speed on TDS, Cl, Br, and SO_4 removal efficiency by EC method. As the speed was changed from 250 to 500 rpm, the maximum treatment performance was achieved. TDS removal performance improved from 85 to 91 percent, Cl from 87 to 93 percent, Br from 86 to 92 percent, and SO_4 from 80 to 90 percent, according to the findings. When the agitation speed was increased from 500 to 750 rpm, the removal performance of TDS, Cl, Br, and SO_4 decreased to 87 percent, 87 percent, 86 percent, and 78 percent, respectively, as seen in Fig. 9. This can be explained by the fact that extreme stirring pace can cause the flocks to break apart

(Moises et al. 2010). Likewise, the higher the stirring level, the more energy was used by the agitator, necessitating higher costs. As a result, the best stirring speed was calculated to be 500 rpm.

CONCLUSION

Water management is critical to ensure that people have access to safe drinking water. Finally, the current research looked at the efficacy of the EC system with iron electrodes for extracting salts TDS, Cl, Br, and SO_4 from aqueous settings. The effects of current (I), passage time (RT), pH, the distance between electrodes (IED), and speed of stirrer (Mrpm) on salt removal were also considered. I = 0.8 A, RT = 80 min, pH = 8, IED = 1 cm, and Mrpm = 500 were the superlative settings achieved. The removal of salts from salty water using EC with a monopolar electrical attachment of iron electrodes is very efficient. The removal efficiencies for TDS, Cl, Br, and SO_4 were 91 percent, 93 percent, 92 percent, and 90 percent, respectively, when the EC process was run under superlative settings. The outcomes of this analysis showed that electrocoagulation is a technically feasible method for removing salts from aqueous settings.

ACKNOWLEDGMENT

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