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PERFORMANCE EVALUATION OF ELECTRO COAGULATION PROCESS FOR THE TREATMENT OF GROUNDWATER

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ABSTRACT

This work include groundwater treatment of Al Hashimia region in Babylon governorate using electrocoagulation (EC) technology. The groundwater characteristics were total dissolved solid (TDS), electrical conductivity, total hardness (TH), and Turbidity. Several parameters are investigated such as applied current density (I), electrodes material; time (RT), pH, interelectrode distance (IED) and mixing speed (MS). The results showed that the maximum removal efficiencies were 91% TDS, 91% electrical conductivity, 92% TH, and 92% turbidity. The optimal parameters of EC process were I= 0.8 A, Al-Al materials, pH=7.12, RT= 80min, IED=1cm and MS=500 rpm. EC process is comfortable technology for groundwater treatment. Treated groundwater can use for multipurpose such as drinking, irrigation, and industry.

KEY WORDS : Removal efficiency, Electrocoagulation, Operating parameters, Groundwater, Al Hashimia region.

INTRODUCTION

The groundwater should be dealt with appropriately to diminish or annihilate the toxins and accomplish the virtue level to advance sustainability (Barrera-Díaz *et al.*, 2012). The significant foreign substance of groundwater is colloidal components, pungent, hard, and turbid (Khandegar *et al.*, 2013; Naje *et al.*, 2016). Coagulation is a compound treatment utilized preceding sedimentation in water and wastewater treatment. It is a cycle for joining little particles into bigger totals. The primary disadvantages of this treatment technique are low evacuation effectiveness, long confinement time, and huge amount of slop. Also, coagulation requires huge amount of synthetics for coagulation, flocculation, pH, and conductivity change, which makes the cycle uneconomical (Yildiz *et al.*, 2008). Numerous innovations like organic oxidation, substance oxidation, progressed oxidation, nanofiltration, and adsorption have been examined. Notwithstanding that, electrochemical innovations, for example, electro testimony, electro coagulation (EC), electro buoyancy (EF), electro oxidation (EO), and electro active remediation, have gotten critical consideration throughout the long term. Their notoriety is because of the simplicity of circulation and moderate required measure of synthetic compounds (Naje *et al.*, 2016). Be that as it may, a large portion of the previously mentioned techniques have some significant disadvantages. For instance, natural oxidation is without a doubt a modest cycle, yet the presence of harmful or bio refractory atoms may prevent this methodology because of effluents' pollution with natural mixes. Compound oxidation has low limit rates and needs transportation and capacity of perilous reactants progressed oxidation measures require high venture costsnano filtration and adsorption measures are not generally adequate to accomplish as far as possible and EO and electrodeposition measures need long response times to accomplish the treatment (Panizza *et al.*, 2009; Martinez-Huitle and Ferro, 2006; Chen 2004). Alternately, EC is a successful wastewater treatment method for expulsion of contaminations. EC has been perceived to adequately treat wastewater from steam cleaners, pressure washers, material assembling, metal platters, and meat and poultry processors (Vepsäläinen, 2012). It is likewise compelling for treating wastewater from business clothing, mining activities, city sewage, and palm oil effluents (Verma *et al.* 2012). In the EC framework, various responses occur at the cathode and the anode. The arrangement of coagulating particles happens in situ through different stages: Formation of coagulants by electrolytic oxidation of the 'conciliatory cathode (anode); Weakening of the poisons, particulate suspension, and breaking of emulsions; and Accumulation of the subverted stages to frame flocs. Pressure of the diffused twofold layer close to the charged particles through the communication of the particles created by oxidation of the conciliatory anode. Charge counterbalancing of the ionic species existing in arrangement by counter particles wound by means of the electrochemical disintegration of the conciliatory anode. These counter particles decline the electrostatic between molecule aversion to the degree that the van der Waals fascination wins, subsequently bringing about coagulation. The floc framed through the coagulation creates a muck cover, which yields and scaffolds the colloidal species in the watery stage. The strong oxides, hydroxides, and oxyhydroxides produce the dynamic surfaces for the adsorption of the foreign substances (Roopashree *et al.,* 2014; Linares-Hernández *et al.,* 2009). This examination presents EC measure for treatment of groundwater in Al Hashimia district. The points of the flow study are to treat the ground water of Al-Hashimia city, Babylon governorate-Iraq utilizing electrocoagulation process and to locate the best operational states of treatment.

MATERIALS AND METHODS

Characteristics of groundwater

Ground water are collected from Babylon governorate- Al-Hashimia township area with depth 9 m. The groundwater characteristics are listed in Table 1.

Experimental setup and procedure

Figure 3.1 illustrates the experimental setup of the EC process used in the present study. The reactorwas performed in a batch made of glass being made. The groundwater was tested for parameters such as total dissolved solid (TDS), electrical conductivity, Total hardness (TH) and Turbidity. The reactor size used in the experiment had a length of 20 cm, width of 15 cm and depth of 15 cm. The volume of treatment water was 4.5 L for each run. Six aluminum plates were connected in parallel with the main power supply where the anode and cathode were both monopolar. The electrode dimensions were 10 × 10 cm^2 and 0.1 cm thickness, with the distance between the interelectrodes being 1 cm. Each electrode had a surface area of 100 cm^2 (10 cm × 10 cm). The collection of electrodes was flooded into the groundwater. The anode and cathode group were linked to negative and positive terminals with a DC power supply. A magnetic stirrer was used to mix the electrolyte. and positive terminals with a DC power supply. A magnetic stirrer was used to mix the electrolyte.The anodic and cathodic reactions took place on the surface of the inner electrodes when the electric current was passed through the electrodes. In the present study, the DC power supply used was made by YIZHAN, 0–40 V; 0–6 A, China. The effect of the applied current was investigated using different current densities (0.2, 0.4, 0.6, 0.8, 1 and 1.2 A) during 100 minute of reaction time. Reaction time were determined at 20 to 100 min, pH was ranged from 5 to 11, inter-electrode distance (IED) was ranged from 0.5 to 2 cm and mixing Stirring speed (MS) were set at 250 to 750 (rpm). All analyses were tested for 92 runs to obtain the optimal condition and the optimal conditions were repeated in 3 replicates to ensure the accuracy and reliability of the results. The applied current was controlled to be stableand constant during the experiment using the programmable power supply by YIZHAN. After every run, the electrodes were completely washed with distilled water. The experiments were carried

Table 1. Characteristics of groundwater

Properties	values
pH	7.12
EC (µs/cm)	60200
TDS (mg/l)	37128
Turbidity (NTU)	390
Total Hardness	550
CL (mg/l)	160
SO_4 (mg/l)	45
Br(mg/l)	6.00
K(mg/l)	30
Na(mg/l)	110
Mg(mg/l)	11
Ca (mg/l)	50

out in the laboratory and the temperature in the laboratory was set to approximately 26–28 °C. The pH of the groundwater was adjusted to the required value using concentrated hydrochloric acid and sodium hydroxide.

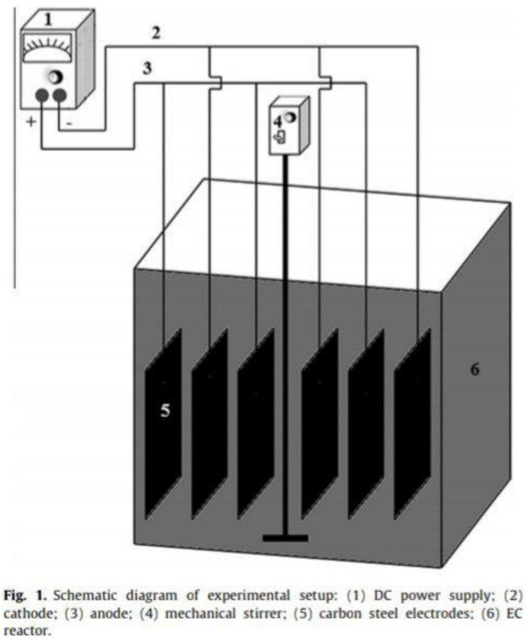

Fig. 1. Schematic diagram of experimental setup: (1) DC power supply; (2) cathode; (3) anode; (4) mechanical stirrer; (5) Aluminum electrodes; (6) EC reactor.

Parameters analysis

Table 2 shows the method of measuring and devices that used for ground water pollutants before and after treatment. The present study deals with removal of TDS, electrical conductivity, TH and Turbidity of groundwater.

RESULTS AND DISCUSSION

Effect of applied current and time

The applied current (I) and reaction time (RT) are two important parameters playing a critical role in regulating the reactor rate within the process of the EC. In the present study, experiments were conducted to find the percentage removal of TDS, electrical conductivity, TH and turbidity at various applied current densities (I = 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2) and various reaction time (20, 40, 60, 80 and 100). The effect of applied current (I) and reaction time on removal efficiencies are presented in Figures (2, 3, 4 and 5). The efficiency of EC process rising with an increase in reaction time. The best removal efficiencies are found at I= 0.8A and RT= 80 minutes. The best removal efficiencies were 91% TDS, 91% electrical conductivity, 92% TH, and 92% turbidity. After 80 minutes, there is a small and non-significant increase in removal efficiencies that leads to an increase in energy consumption (UT *et al.*, 2015). Therefore, 0.8 A and 80 minutes were selected as the best operational factors that also in line with the results obtained in the previous studies (Naje *et al.* 2018; Naje *et al.*, 2019).

Table 2. Parameters and methods of the analyses

Meter/method	Parameters
pH meter -pHM84	pH
TDS meter (TDS-EZ, HM Digital)	TDS
HANNA HI-99301	Electrical conductivity
HACH 2100P	Turbidity
Gravimetric	Total hardness (TH)

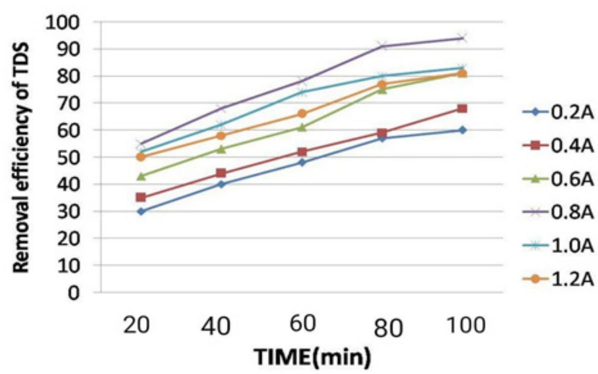

Fig. 2. Effect of applied current on TDS removal efficiency

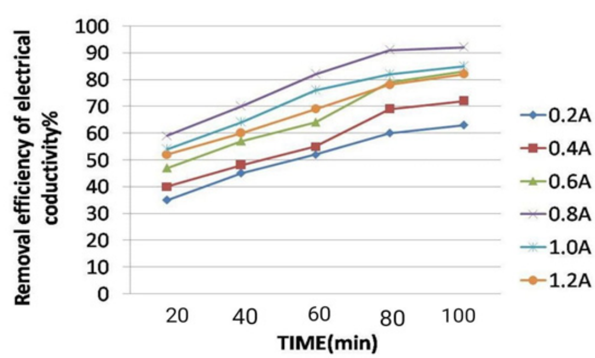

Fig. 3. Effect of applied current on Electrical conductivity removal efficiency

Effect of pH

The importance of the effect of pH on water treatment in the EC method has been stated by

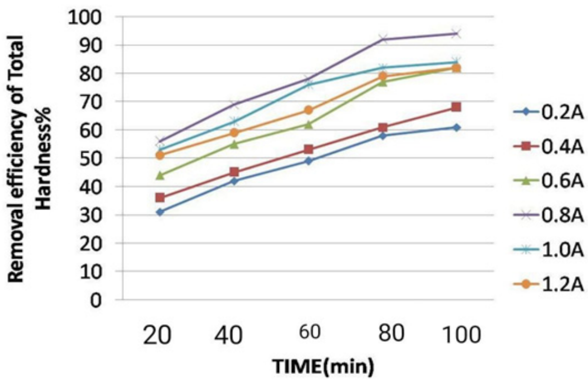

Fig. 4. Effect of applied current on Total Hardnss removal efficiency

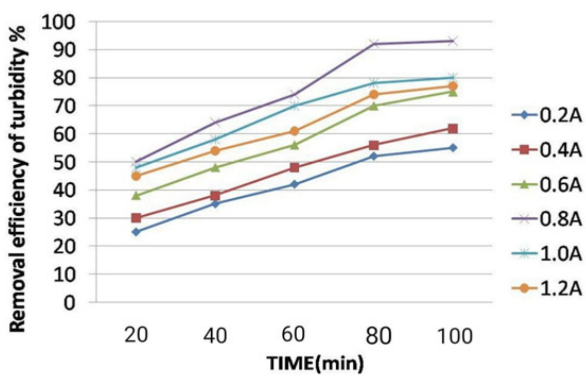

Fig. 5. Effect of Applied current on Turbidity removal efficiency

previous studies. In the present study, the effect of pH on TDS, electrical conductivity, TH and Turbidity removal were investigated by adjusting the initial pH in the interval pH from 5 to 11 with optimum conditions Al- Al, I = 0.8 Aand reaction time of 80 minutes. Figure 6 shows that at pH 8 the efficiencies for removal of TDS, electrical conductivity, TH and Turbidity were little enhanced to 91%, 93%, 92% and 90%, respectively. The increase of pH levels is attributed to the present of water electrolysis that lead to the production of hydrogen and (OH) ions. Afterward, pH is considered relatively stable which could be attributed to the formation of the insoluble M $(OH)_3$ flocs and the metal hydroxide (Bagga *et al.*, 2008). The results show the reduced levels of solubility in aluminum hydroxide at pH values of 4 and 5 in acidic phase and 9, 10 and 11 in alkaline phase. These findings are in agreement with optimum pH level found in the present study. The normal pH of groundwater is the best.

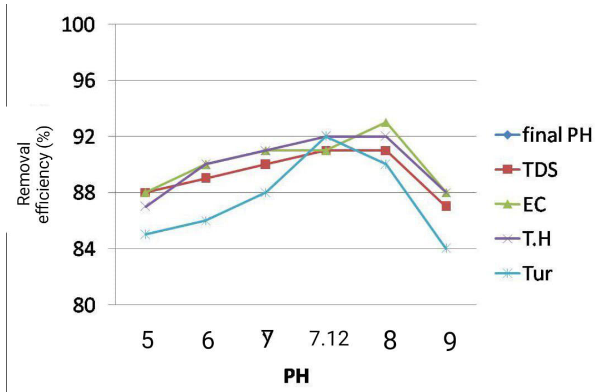

Fig. 6. pH effect at optimal conditions.

Effect of Inter-Electrode Distance

The electrode assemblage set-up is crucial to obtain an effective surface area of the electrode and inter-electrode distance (IED). Increase in distance between the two electrodes leads to increase in resistance between the electrodes. Hence, this leads to reduction of electrical current values. However, increase of distance between electrodes leads to less interaction between ions and hydroxide polymers, as expected theoretically. Literature studies proved the importance of the effect of the IED on removal efficiency in the EC method. The variation in voltage drop (ηIR) is governed by the following equation (Lekhlif *et al.,* 2014):

$$\eta IR == I.(d/s*k) \quad .. (1)$$

Where I represents the electric current, measured in Amperes (A), d is the length of distance between the two electrodes in meters (m), S is the active anode surface area in meter-square (m^2), k is the specific conductivity in micro-Siemens per meter (µs/m). This equation implies that voltage drop will increase with increase of inter-electrode distance (IED) at constant anodic surface area and conductivity of the solution. In the present study, the effect of IED was examined using 0.5, 1, 1.5 and 2 cm by using Al- Al, I = 0.8A, RT = 80 minutes, and pH = 7.12 as optimum conditions, showed in Fig. 7. The best performances were achieved with 1 cm as middle distances. The obtained results were 90 to 91% for TDS, 92 to 91%forelectrical conductivity, 90 to 92% for TH and 88 to 92 % for turbidity for a modification of the distance from 0.5 to 1 cm. On the other hand, the expansion of the distance from 1.5 to 2 cm led to declining treatment efficiencies of 90 to 87 % for TDS, 91 to 88% for electrical conductivity, 90 to 87 % for TH and 87 to 82 % for Turbidity. The influence of the final IED on the performance of contaminants removal was explained by the previous studies that found the mansionin the inter-electrode distance (IED) led to a decline of electrodes attraction (Daghrir *et al.,* 2012; Katal and Pahlavanzadeh, 2011). This was observed on the generated iron polymers that adversely affects the EC process.

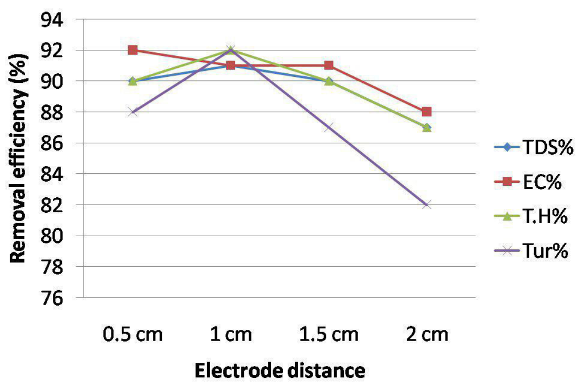

Fig. 7. Effect of inter-electrode distance under optimal condition

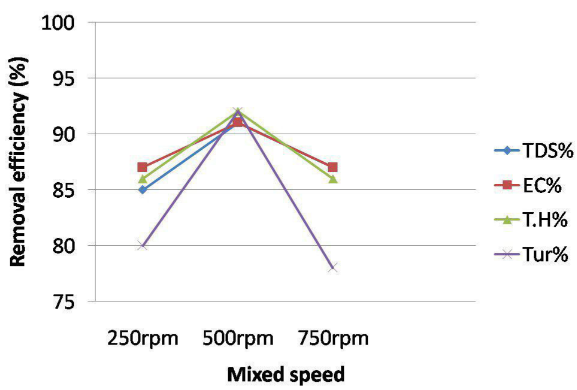

Fig. 8. Effect of mixer speed under optimal conditions

Effect of Stirring Speed

Mixing stirring speed (MS) is an influential factor in the EC process. When raise stirring rate, pollution is formed, monopolar and attached together, thus precipitation and mass transfer becomes easier (Heidmann and Calmano, 2008; Naje *et al.,* 2019). While the reverse effect occurs with rise of the stirring rate more than needed will make the contaminants that are formed within the reactor degraded and create smaller flocks that are difficult to separate from solution. This action causes a decrease in treatment efficiency. In order to investigate the effect of agitation speed on TDS, electrical conductivity, TH and Turbidity removal efficiency by ECprocess, stirring speeds of 250, 500 and 750 rpm were performed using optimal conditions; Al-Al, I = 0.8 A, RT = 80 min, and pH = 7.12. The highest treatment efficiency was obtained when speed was increased from 250 at 500 rpm. The results show the TDS removal efficiency has increased from 85 to 91%, electrical conductivity from 87 to 91%, TH from 86 to 92% and Turbidity from 80 to 92%. Lower results were obtained when the agitation speed was raised from 500 to 750 rpm, where the TDS removal efficiency decreased to 87%, electrical conductivity to 87%, TH to 86% and Turbidity to 78%, as shown in Fig. 8. This can be interpreted by the fact that excessive stirring speed can lead to resulting in the breaking of the flocks (El-Ashtoukhy *et al.*, 2013; Singh *et al.*, 2014; Bayar *et al.*, 2011). Furthermore, the higher was the stirring speed, the increased energy the agitator consumed and thus need more cost. Therefore, this is why 500 rpm was chosen as the best stirring speed.

CONCLUSION

Groundwater treatment is essential in ensuring access to clean water supply. In conclusion, the present study evaluated the applicability of EC method using iron electrodes in the removal of groundwater contaminants (TDS, electrical conductivity, TH and Turbidity from aqueous environments. Furthermore, the effects of current (I), reaction time (RT), pH, distance between theelectrode (IED) and stirrer speed (rpm) on the removal efficiencies were investigated. The optimal conditions achieved were: I = 0.8 A, RT = 80 min, pH = 8 , T = 25°C, IED = 1 cm and Mrpm = 500. EC under monopola relectrical connection of aluminum electrodes was proven to be very efficient for treatment of groundwater. Using the optimal conditions of the EC process, the removal efficiencies were 91%, 91%, 92% and 92% for TDS, electrical conductivity, TH and Turbidity, respectively. The findings of the present study revealed the technical feasibility of electrocoagulation as a reliable technique for groundwater treatment from aqueous environments.

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