Water Purification By Removing Chemical Materials From Water By Electrochemical Methods

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Abstract

The current Study gives an Electrocoagulation Process for the Reduction of Nitrate Ions from Aqueous Solutions, to Meet the Standards of Water for Drinking Purposes.The effect variables such as pH $_{Init}$, Current Density (i), Temperature (T), and Time (t) on the Reduction Efficiency was studied in Batch Reactor Using Aluminium Electrodes. The Optimal Reduction Conditions Were Proposed to be at pH = 7, Temperature of 30◦ C, Current Density 2.604 $mA.cm^{-2}$ and Time of 120 min. The Results Showed that the Reduction Percentages for NO_3^- were 88.18% by Using Al Electrodes at 120 min. The Electrode Consumption was (0.167) kg/m^3 and the Mean Energy Consumed was W_{SP}= (3.5) kWh/m^3.

Keywords: Electrocoagulation, Al–Al Electrodes, Removal Efficiency, Nitrate Ions.

1. Introduction

Many ways have been studied for the Reduction of NO_3^- from Water, like Reverse Osmosis, Electro-dialysis, Adsorption [2 ,5 ,7], Advanced Oxidation and Biological Denitrification [9, 10]. Modern Water treatment methods have been Developed Including Electrochemical, Chemical [1]. Electrocoagulation Method has been performed for Water and Waste Water treatment. In the Electrocoagulation Method, electrochemically generated aluminium hydroxide flocks can remove nitrate ions by Adsorption, Precipitation and Floatation [6,10,14]. Electrocoagulation is economical Process for the Treatment of polluted Water, Drinking Water [4, 5, 11], Olive Oil Mil Waste Water(OMW), Textile Waste Water, Industrial Waste Water [1, 12, 15].

This Work performed to Examine the Possibility of Effective Reduction of Nitrate from Synthetic Solution [8, 9].

This Process Receives Attention due to its Advantages such as Safety, Environmental Compatibility, Versatility, and Cost Effectiveness, Etc .

2. Experimental Setup

2.1 Reagents and analytical procedures

The Material tested in The Work was $NaNO_3$ Solution which were Prepared at a Concentrations of 137 mg/L equal to 100 mg NO_3^-/L.

The Standard Solution of 200 ml of $NaNO_3$ (137 ppm) was Used for the Electrocoagulation.

Electrocoagulation (EC) was used to Synthetic Water Using a 500 ml cylindrical Tank, and a digital Power Supply with Variant Current Density, Al – Al Electrodes were (48) mm X (20) mm, effect Surface of 19.2 cm^2, and Distance between Electrodes was D= 2 cm. The Current Density (i) was Constant by DC

Power Supply (U: 0 – 16 Volt and Current : 0 – 5 A). The Nitrate Concentrations were Analysed Using a UV-Vis Spectrophotometer Dr 5000 at λ_{max} = 400 nm. A pH meter Model inolap pH Level 2 .

2.2 Analysis

The Nitrate Reduction Efficiency in the Treatment Experiments was Calculated by Relation:

$$RE \% = [(C_{in} – C_{out}) /C_{in}] * 100$$

Where:

C_{in} and C_{out} are Concentrations Values of Nitrates Solution before and after Treatment.

2.3 Results and Discussion:

The Main Processes happening During Electrolytic Reactions:

Formation of Flocks in Aqueous solution, Adsorption of nitrate ions on Coagulants, Sedimentation or Floatation [3, 9]. They Take place according to the Mechanisms [9]:

At Positive electrode:

$$Al_{(solid)} \rightarrow 2\ Al^{3+}_{(dissolve.)} + 6\ e^-$$

$$2\ Al^{3+}_{dissolve.} + 6\ H_2O \rightarrow 2\ Al\,(OH)_{3\,(solid)} + 6\ H^+_{(dissolve.)}$$

At negative electrode:

$$6H^+_{(\ dissolve.)} + 6\ e^- \rightarrow 3\ H_{2\,(gas)}$$

2.4 Total:

$$2\ Al_{(solid)} + 6\ H_2O \rightarrow 2\ Al(OH)_{\ 3(solid)} + 3\ H_{2\ gas}$$

2.5 Determination of Optimum Current Density (mA.cm^{-2}):

This parameter have an important effect on the Nitrate Ions Reduction.

To tested the impact of i on Reduction Effectiveness, a group of Experiments were performed with i = (0.5208 -1.5625- 2.604 mAcm^{-2}) at pH_{init} = 7, Concentration of 137 mg $NaNO_3$/L, Distance between electrodes D =2 cm and Temperature of 30° C.

Figure (1) shows the Optimum i was 2.604 mAcm^{-2}. the Reduction Effectiveness of Nitrate was 88.18 % at 120 min.

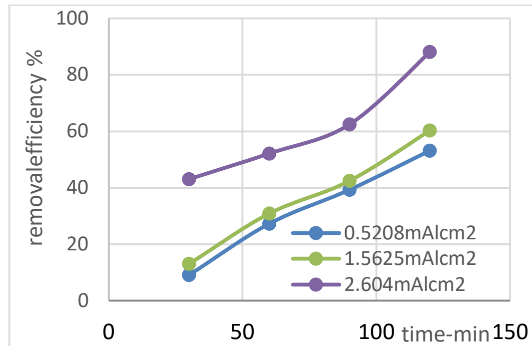

Fig 1. impact of i and EC time on the reduction Effectiveness of nitrate with Al-Al electrodes. $C_{INITIAL}$ 137 mg $NaNO_3$/L, pH=7, T=30° C.

2.6 Determination of Optimum pH :

To Assess the Effect, a group of Experiments were Performed Using Solutions with an Initial pH in the Range (3-9) at Initial Concentration of Nitrate Ions 137 mg/L as $NaNO_3$. Distance between Electrodes D=2 cm, Temperature of 30 ° C and Current Density i= 2.604 mAcm^{-2} at time 120 min. Figure (2) shows that the Reduction Effectiveness of Nitrate Ions were weak in Acidic solution, meanwhile, in Natural and Moderate alkaline solution, the Reduction Effectiveness was much higher because of the Formation of aluminium Hydroxide colloids which Adsorb the Nitrate Ions.

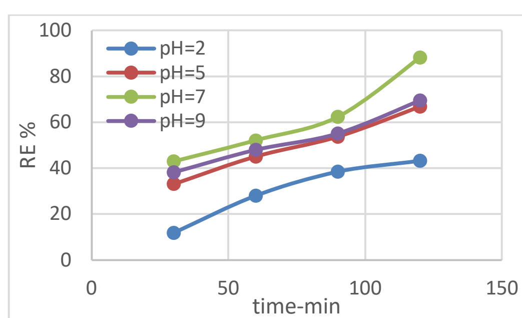

Fig 2. impact of Operating time and pH on the reduction Effectiveness of nitrate using Al-Al

electrodes. CINITIAL 137 mg $NaNO_3$/L, T=30° C and current Density 2.604 $mAcm^{-2}$.

2.7 Determination of optimum temperature (° C) :

The impact of coagulattion Temperature in the range 20 to 50 ° C has been performed for the Reduction Efficiencies of Nitrate Ions as shown in Figure (3) at t = 120 min. C_{init}=137 mg $NaNO_3$/L , pH_{init} = 7 and Current Density i= 2.604 $mAcm^{-2}$ Using Al Electrodes. The Figure (3) show that the NO_3^- Reduction Efficiency Decrease at Temperatures above 30 ° C because of the $Al(OH)_3$ Colloids will Decrease.

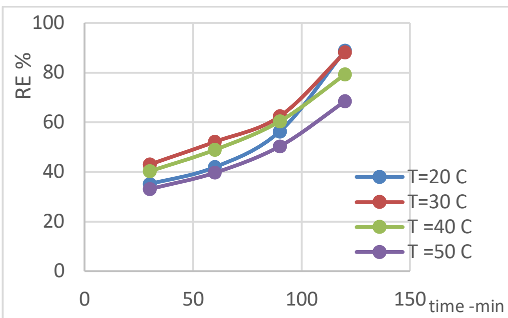

Fig 3. impact of Operating time and Temperatures on Nitrate Reduction Efficiencies, Using Al Electrodes (current Density i= 2.604 $mAcm^{-2}$ and pH_{init} = 7).

2.8 Determination of optimum Operating Time: The optimum time gives highest nitrate reduction value. In this paper, the impact of coagulation Time on Nitrate Reduction Efficiency Using Al Electrodes were (43.02- 52.12- 62.42- 88.18) % at t= 30-60-90-120 min. Figure (4) show that the best results given where at Operating Time 120 min.

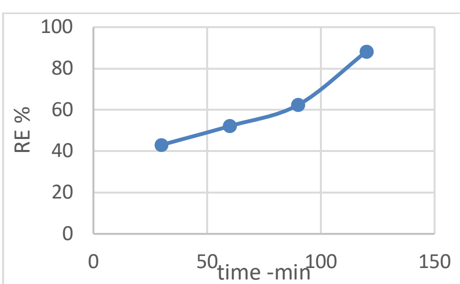

Fig 4. influence of coagulation time on Nitrate Decrease Efficiencies, Using Al Electrodes (current Density i=2.604 $mAcm^{-2}$, pH = 7, initial concentration C_{init} =137 mg $NaNO_3$/L and T=30° C).

2.9 Evaluation of the specific power Consumption W_{sp}:

The Specific Power Consumption W_{sp} ($kWh.m^{-3}$) is calculated using Equation:

W_{sp} = I. U . t / V_{sample}

U= 7 volt, I =0.05 A and t = 120 min (2 h). under optimal conditions W_{sp} = 3.5 ($kWh.m^{-3}$).

2.10 The theoretical consumption of Electrode:

The theoretical mass of Al Electrochemically Generated from Anode was Calculated Using Faraday's Low [13]:

$$m_{Al,th} = \frac{(I * MAl * t)}{V*Z*F} \quad (kg/m^3)$$

m_{Al} : the Mass of the Dissolved Anode Material.

I : Current Intensity I= 0.05 A.

M : the Atomic Mass ,M=27 .

t : operating time t= 120*60 = 7200 sec.

V : Volume of the sample = $0.2 * 10^{-3}$ m^3

Z : the Charge Number.

F : the Faraday's Constant.

The Maximum value was 0.167 $kg.m^{-3}$ at 120 min and current density 2.604 $mAcm^{-2}$. the Electrode consumption at i= 2.604 $mA.cm^{-2}$ pH=7, T= 30 ° C was increased from 0.04176 $Kg.m^{-3}$ during the first 30 min to 0.167 $Kg.m^{-3}$ at t = 120 min, while the reduction efficiencies were in ranging (43.02 - 88.18) %.

3. Conclusions

The Treating of Nitrate Ions in synthesis water using Aluminium Electrodes was affected by many variables such as Current Density i, pH_{init}, Initial Temperature and time.

Electrocoagulation is an Effective, simple, Fast method.

Nitrate Removal was 88.18 % Using Al Electrodes at 120 min.

Electrical Energy Consumption was 3.5 $Kwh.m^{-3}$ Using Al Electrodes. At i = 2.604 $Ma.cm^{-2}$, pH = 7, Nitrate Concentration 100 mg NO_3^-/L, Distance between Electrode 2 cm and Temperature 30 °C.

The theoretical Mass of Loss from Electrode was 0.167 kg/m^3.

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