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Treatment of Groundwater by Using the Electrocoagulation Technique

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Abstract: This research carried out experimental runs to present a solution for treatment of groundwater by using electrocoagulation (E.C) technique to remove different elements such as heavy metals (iron, manganese), Turbidity, Total Alkalinity, Conductivity, pH, TDS, Fluorides, Magnesium, Sulfate (SO_4), Magnesium carbonate ($MgCo_3$). The influence of various operating parameters of Electrocoagulation technique, such as retention time, current intensity, and distance between electrodes were explored for effective treatment of ground water, where Aluminum sheet was used as the electrode material, distance between electrodes was varied from 0.5 cm to 2 cm and the current intensity was varied from 1.5 to 4.5 ampere with retention time from 20 to 60 min.

The experimental results found that the best removal efficiencies for iron, manganese, turbidity, total alkalinity, conductivity, TDS, fluorides, magnesium, sulfate, and $MgCo_3$ were 89.9%, 75.42%, 92.06 %, 49.85 %, 23.09 %, 23.09 %, 90 %, 43.39 %, 26.6 %, and 43.71 % respectively.

Keywords: Groundwater, Electrocogualtion, Aluminium Electrodes

1. Introduction

Population increase, improving the standard of living and industrial and technological progress has led to decrease in the per capita share of water. Groundwater resource is one of the non-conventional water resources. Groundwater is found in the Arab Republic of Egypt, mainly in four regions, namely Nile Valley and Delta - Western Desert - Eastern Desert – Sinai (National water resources plan for Egypt 2017).

With the increase in the demand for drinking water, the use of groundwater as a source of water has become a necessity in most countries of the world (Ashour et al, 2009).

As groundwater contains some heavy metals such as iron, manganese, and others, so treating water from these minerals is a very vital step to ensure the safety of using this water for drinking. Increased demand for drinking water has led to increase groundwater use, which has become the key source of supply for many regions of the world, including Latin America 50% percent of the global population is estimated to meet their groundwater water requirements (Jadhav et al., 2015). For more than half of the world's population, groundwater is the main source of drinking water (Margat and Van der Gun, 2013) and is generally considered to have better water quality than surface water, often being consumed untreated. Even though groundwater does not contain high levels of microbial contamination, its quality may be compromised by naturally occurring (geogenic) contaminants such as arsenic and fluoride. Even though microbial contamination is usually prioritized due to its immense a crisis of disease and associated childhood mortality (Pruess-Ustuen et al., 2014), Geogenic pollution is also blamed for serious health consequences. Generally, groundwater, as a

source of drinking water, is considered cleaner than surface water. Pollutants may, therefore, compromise its efficiency (Bretzler and Johnson, 2015). The objective of this research was to suggest a new configuration for an electrocoagulation reactor, which separated by a glass wall into electrochemical, and separation units and investigate the ability of this new reactor to remove pollutants from ground water to use it as drinking water.

2. Materials and Methods

2.1Sample Site

The sample was collected from Al Khusous Water Station, Fig (1).

Fig (1): Al Khusous Water Station Sample collection site

2.2 Sample Collection and Preservation

A sample was collected from ground well, collected over a period of 8 hours, at a sampling rate of 1.5 lit/hr. Total volume 10000 ml (10 liters / 8 hours). The container was kept in a box, so that all samples were temperature-controlled during sampling and transported from the plant to the Workplace experience.

2.3 Measured Parameters

Analysis was done for well groundwater to determine the heavy metals (iron, manganese), Turbidity, Total Alkalinity, Conductivity, Fluorides, TDS, Magnesium, Sulfate and Magnesium carbonate. Then experiments were made to treat the obtained samples of groundwater by using the electrocoagulation technique, where the relationship between the retention time and the applied voltage will be studied and post water analysis will be made; to identify the rates of removing heavy metals, as well as the best retention time, the best applied current density, and the possibility of using it as drinking water.

2.4 Model Description

The model components were shown in Figs (2), and (3). The model consists of one tank divided into two stages; the first one includes water inlet, aluminum electrodes, Flotation unit, and settling unit. The second stage is sedimentation tank, DC power source (TE-5305) was used as current or direct electric source to be applied during electrocoagulation treatment of groundwater. Aluminum electrodes were used as the working electrode in the electrolyte cell and connected to the positive terminal and the negative terminal of the DC power, the circulation pump to circulate the water to the electrocoagulation system.

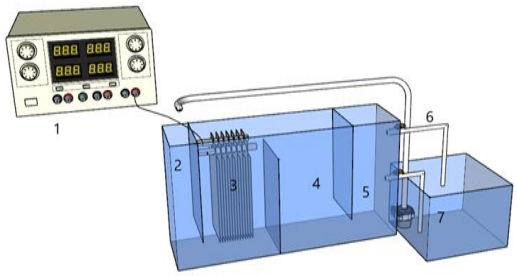

Fig (2): A schematic Diagram of the E.C
(1. DC Power source. 2. Water inlet. 3. Al Electrodes. 4.Flotation unit.5. Settling unit. 6. Water outlet. 7. Final storage and circulation pump)

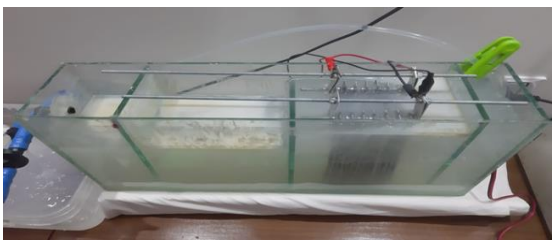

Fig (3): A Photograph of the EC Process

3.Experimental Method

The aim of this research was to suggest a new configuration for an electrocoagulation reactor, which separated by a glass wall into electrochemical, and separation units and investigate the ability of this new reactor to remove pollutants from ground water to use it as drinking water. The characteristics of groundwater sample are shown in table (1)

Table (1) Characteristics of Groundwater Sample

Parameter	Value		Parameter	Value	
pH	8		TDS	597.6	mg/l
Fe	0.99	mg/l	Fluorides	0.24	mg/l
Mn	1.18	mg/l	Magnesium	39.974	mg/l
Turbidity	4.28	mg/l	Sulfate	82.218	mg/l
Total Alkalinity	327	mg/l	$MgCo_3$	167	mg/l
Conductivity	996	mg/l			

The new E.C reactor was constructed of a bench scale glass basin for experimental work at a room temperature. The electrocoagulation reactor consists of 10 liter Pyrex glass basin and fourteen electrodes (20 cm high, 8 cm wide and, 0.15 cm thickness) which were fixed vertically and parallel to each other and they are connected to a variable power supply (TE-5305, 0-30V/0-5A) in a monopolar configuration and the internal spacing between the two electrodes was 0.5 cm to 2 cm. The reactor was separated by a glass wall into electrocoagulation and separation units with 5 Lit in each unit. The baffles at the beginning of the first unit and the middle of the second unit were made to equalize the influent velocity and facilitate separation of the scum, respectively. The submerged surface area of each electrode was 160 cm^2. Both of cathodes and the anodes were made of aluminum. The experiment was performed at different detention time (0 – 90 minutes) where the samples were collected at regular interval of time and analyzed for the removal of iron, manganese, total alkalinity, total dissolved solids TDS, Conductivity, Fluorides, Magnesium, Sulfate, Turbidity and $MgCo_3$.

Nine Runs were conducted to determine the optimum treatment conditions (applied voltage, retention time, the spacing between electrodes) to achieve the best removal efficiency.

This study was worked on three parameters which are:

1- Spacing between electrodes. 2. Current intensity. 3. Retention time

4.Result and Discussion

The results showed that the best iron removal percentage was (89.9%) and was performed at current intensity (4.5 amp), retention time (30 minutes) and distance between electrodes (0.5 cm), the best manganese removal percentage was (75.42 %) and was performed at current intensity (3.5 ampere), retention time (45 minutes) and distance between electrodes (1 cm), the best Turbidity removal percentage was (92.06 %) and was performed at current intensity (3 ampere), retention time (30 minutes) and distance between electrodes (0.5 cm), the best Total Alkalinity removal percentage was (49.85 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm), the best Conductivity removal percentage was (23.09 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm), the best TDS removal percentage was (23.09 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm), the best Fluorides removal percentage was (90 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm) and at current intensity (4.5 Ampere), retention time (30 min) and distance between electrodes (0.5 cm), the best Magnesium removal percentage was (43.39 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm), the best sulfate

removal percentage was (26.6 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm) and the best Mg CO_3 removal percentage was (43.71 %) and was performed at current intensity (3 ampere), retention time (60 minutes) and distance between electrodes (0.5 cm).The result of parameters removal as showed in table (2), (3).

Table (2) The result of parameters removal of electrocoagulation treatment

Parameter	Raw water	- Distance (0.5 cm) and current (3 ampere) is constant.			-Time (30 min) and Distance (0.5 cm) is constant.			- Time (45 min) and current (3.5 ampere) is constant.		
		Time variable			Current intensity variable			Distance between electrodes variable		
		20 min	40 min	60 min	1.5 amp	3 amp	4.5 amp	1 cm	1.5 cm	2 cm
Iron (Fe)	0.99	0.4	0.28	0.21	0.33	0.3	0.1	0.15	0.18	0.3
Manganese(Mn)	1.18	0.85	0.67	0.43	0.84	0.59	0.5	0.29	0.35	0.44
Turbidity	4.28	0.71	0.5	0.38	0.77	0.34	0.38	0.78	0.45	0.43
Total Alkalinity	327	257	200	164	234	247	198	262	266	319
Conductivity	996	924	836	766	870	852	828	979	902	890
pH	8	7.6	7.6	7.6	7.6	7.2	7.6	8.2	7.8	7.8
TDS	597.6	554.4	501.6	459.6	522	511.2	496.8	587.4	541.2	534
Fluorides	0.24	0.14	0.045	0.024	0.104	0.05	0.024	0.05	0.054	0.096
Magnesium (Mg)	39.974	34.056	29.783	22.627	32.625	28.728	24.517	30.784	29.988	30.219
Sulfate (So_4)	82.218	63.136	60.569	60.345	71.436	68.432	68.076	71.388	68.742	74.421
$MgCo_3$	167	142	124	94	136	120	102	128	125	126

Table (3) The efficiency of parameters removal of electrocoagulation treatment.

Parameter	Raw water	- Distance (0.5 cm) and current (3 ampere) is constant.			-Time (30 min) and Distance (0.5 cm) is constant.			- Time (45 min) and current (3.5 ampere) is constant.		
		Time variable			Current intensity variable			Distance between electrodes variable		
		R% 20 min	R% 40 min	R% 60 min	R% 1.5 amp	R% 3 amp	R% 4.5 amp	R% 1 cm	R% 1.5 cm	R% 2 cm
Iron (Fe)	0.99	59.6	71.71	78.79	66.67	69.7	89.9	84.85	81.82	69.7
Manganese(Mn)	1.18	27.97	43.22	63.56	28.81	50.00	57.63	75.42	70.34	62.71
Turbidity	4.28	83.41	88.32	91.12	82.00	92.06	91.12	81.78	89.49	89.95
Total Alkalinity	327	21.4	38.84	49.85	28.44	24.46	39.45	19.88	18.65	2.45
Conductivity	996	7.22	16.06	23.09	12.65	14.46	16.87	1.71	9.44	10.64
pH	8	7.6	7.6	7.6	7.6	7.2	7.6	8.2	7.8	7.8
TDS	597.6	7.23	16.06	23.09	12.65	14.46	16.87	1.71	9.44	10.64
Fluorides	0.24	41.67	81.25	90	56.67	79.17	90	79.17	77.5	60
Magnesium (Mg)	39.974	14.8	25.49	43.39	18.38	28.13	38.67	22.99	24.98	24.4
Sulfate (So_4)	82.218	23.21	26.33	26.6	13.11	16.77	17.2	13.17	16.39	9.48
$MgCo_3$	167	14.97	25.75	43.71	18.56	28.14	38.92	23.35	25.15	24.55

5. Conclusions

In this study several tests were conducted to investigate the possibility of use the Electro-coagulation technique to treat ground water. This research was conducted through nine runs each run perforated on different retention time, current intensity and distance between electrodes and the results were as follows: -

1. When the current intensity was (4.5 ampere) with retention time (30 min) and the distance between the electrodes was (0.5 cm) the best result of removing iron, Turbidity and Fluorides is obtained, and the percentage of removal was 89.9 %, 92.06 % and 90% respectively.
2. When the current intensity was (3.5 ampere) with retention time (45 min) and the distance between the electrodes was (1 cm) the best result of removing manganese is obtained, and the percentage of removal was 75.42 %.
3. When the current intensity was (3 ampere) with retention time (60 min) and the distance between the electrodes was (0.5 cm) the best result of removing total alkalinity, conductivity, TDS, Fluorides, magnesium, sulfate and $MgCo_3$ is obtained, and the percentage of removal was 49.85 %, 23.09 %, 23.09 %, 90 %, 43.39 %, 26.6 % and 43.71 % respectively.

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