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GROUND WATER ASSESSMENT AND ITS ELECTRO CHEMICAL TREATMENT

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ABSTRACT

In the present study, groundwater quality assessment and its electrochemical treatment was carried in Dwarka district, Delhi. Water samples were collected and analyzed to find out its suitability for drinking purpose. Different parameters such as pH, electrical conductivity, total dissolved solids (TDS), total hardness, nickel, chromium were analysed. The results obtained were compared with the Indian standard drinking water specifications (IS: 10500). The results showed that the ground water quality was not suitable for drinking purpose. Recently, researches have revealed electrochemical (Electrocoagulation) as an attractive and suitable treatment method for water including groundwater because of the various benefits which include environmental compatibility, flexibility, energy efficiency, safety, selectivity, amenability to automation, and cost effectiveness. Therefore, electrocoagulation was carried out to remove hardness from groundwater. The removal efficiency was measured in terms of hardness with time and current density as variables. The results show that electrocoagulation may also be used for water hardness reduction.

Keywords: Delhi, Electrocoagulation, Groundwater, Hardness, Quality

I. INTRODUCTION

Water is critical for sustainable development, environmental integrity and the mitigation of poverty and hunger, and is indispensable for human health and well-being. Nearly 2.4% of the total global water is dispersed on the main land, out of which only a small portion can be utilized as fresh water. Groundwater forms an important source of fresh water supply throughout the world, as it is not only essential for the lives of animals and plants, but also occupies a unique position in industries. Groundwater is a source of drinking water for at least 50% of the world population. Groundwater gets polluted / contaminated as a result of human activities including extensive use of pesticides, herbicides and fertilizers, leaking fuel and chemical tanks, industrial chemical spills, drainage of house hold chemicals and badly managed landfills etc. Due to the contamination, safe drinking water scarcity is becoming a significant problem throughout the world. The lack of clean ground water resources and safe drinking water has been recognised and analysed by different international and national organisations such as the World Health Organisation and water treatment is recommended before use.

Groundwater quality of Delhi requires attention because there is a continuous decline in water level and quality due to rapid urbanization and industrialization. Dubey et al. analysed the groundwater quality of Dwarka district in Delhi. They collected and analysed 26 samples of the ground water from the bore wells in Dwarka and nearby areas. They concluded that 30.77% of samples tested have been found unfit for drinking, 46.15% samples have very poor quality and 19.23% of samples belong to the poor category of water quality [1]. Therefore groundwater quality of Dwarka needs greater attention since it is the only major source for domestic consumption in this region.

Contaminants found in the groundwater cover a broad spectrum of physical, chemical (Organic & Inorganic), bacterial and radioactive parameters as reported by Kaur [2]. Among water quality parameters, hardness has always been investigated as an important factor. Hard water causes many problems in domestic and industrial usage. Water hardness is due to cations such as calcium, magnesium; and in lower quantity; aluminium, iron and other bivalent and trivalent cations. The growing demands for high quality of soft water necessitate the development of cost-effective and efficient technology [3].

Various physical and chemical technologies such as chemical precipitation, ion exchange, reverse osmosis, electrodialysis, nanofiltration, crystallization, distillation and evaporation are available out of which membrane technology has emerged as a reliable technology for ground water treatment. However, fouling is one of the major challenges for the operation of membrane process resulting in frequent replacement of membrane thus resulting in high costs of water treatment.

Recently, researches have exposed electrocoagulation as an attractive and suitable method. Electrocoagulation process is being investigated for the removal of ions, organic matters, colloidal and suspended particles, dyes, surfactants, oil and heavy metals from various types of water and wastewater such as electroplating wastewater [4, 5], laundry wastewater [6], textile wastewater [7] and restaurant wastewater [8].

Orescanin et al. reported electrocoagulation as suitable treatment for the removal of heavy metals, suspended solids, color and turbidity from groundwater for human consumption. They concluded that electrochemical treatment is a suitable method for the purification of groundwater with complex mixture of contaminants [9].

Zhao et al. developed an integrated electrocoagulation - reverse osmosis (RO) process for simultaneous removal of hardness, COD, and turbidity, where effectiveness of electrocoagulation for the pretreatment of produced water prior to RO membranes was investigated. They demonstrated the practical applicability of the process through analysis of permeate flux and effluent quality in treating produced water from one oil field in Canada[10].

Electrocoagulation process consists of an in-situ generation of coagulant by the dissolution of sacrificial anode. The application of current leads to the generation of hydroxide ions at the anode and hydrogen gas at the cathode. The generation of the hydroxide ions leads to the formation of flocs, which settles the pollutant and can be easily removed by sedimentation. There is formation of gas bubbles, which entrains the lighter pollutants and brings them to the surface of the effluent where they can be removed by floatation. Aluminium and iron metals have been commonly used as electrodes since they are cheap and easily available.

The reactions occurring in an electrochemical cell for an aluminium electrode are as follows:

At the cathode:

$$3H_2O + 3e \rightarrow (3/2)\ H_2(g) + 3OH^-(aq) \quad (1)$$

At the anode:

$$Al(s) \rightarrow Al^{3+}(aq) + 3e \quad (2)$$

In the solution:

$$Al^{3+}(aq) + 3H_2O \rightarrow Al(OH)_3 + 3H^+(aq) \quad (3)$$

Al^{3+} (aq) ions formed in the solution will immediately undergo further spontaneous reaction to generate corresponding hydroxides and polyhydroxides resulting in generation of $Al(H_2O)_6^{3+}$, $Al(H_2O)_5OH^{2+}$, $Al(H_2O)(OH)^{2+}$. The hydrolysis products produce many monomeric and polymeric substance such as $Al(OH)^{2+}$, $Al^2(OH)_2^{4+}$, $Al(OH)^{4-}$, $Al_6(OH)_{15}^{3+}$, $A_{l7}(OH)_{17}^{4+}$, $Al_8(OH)_{20}^{4+}$. These hydroxides / polyhydroxides / polyhydroxymetallic compounds have strong affinity for dispersed particles and cause coagulation. The gases evolved at the electrodes cause floatation of the lighter materials. The electrocoagulation process is characterised by simple equipment, easy operation, a shortened reactive period, no addition of chemicals and decreased amount of precipitate or sludge which sediments rapidly.

Only few studies are reported till date for ground water treatment using electrocoagulation. Thus, this study aims at electrocoagulation treatment of ground water.

II. MATERIALS AND METHODS

2.1. Samples

Groundwater samples location was determined by Garmin GPS Etrex10. The samples were collected with necessary precautions in plastic cans from Dwarka sub-city which is located in the south west Delhi as detailed in Table 1. The samples were stored under suitable temperature till the analysis was done.

Table 1. Location Details of Groundwater Samples Collected from Dwarka and nearby areas

Sample No.	1	2	3	4	5
Address	Sec-19 Poc.2 DDA Park Well 1	Sec-5, Central Nursery, DDA	Shiv Mandir Goyala dairy road	Goyala dairy	Sainik Nagar, Mansa Ram Park I
Location (N,E)	28.34.916' 077.02.800'	28.35.570' 077.03.453'	28.34.626' 077.02.057'	28.34.840' 077.01.259'	28.37.010' 077.02.493'
Depth (ft)	200	300	70	170	120

2.2 Chemicals

All the chemicals used were of AR grade and procured from Thomas baker and qualigens. During the analysis and experiments, double distilled water was used.

2.3 Analysis

The parameters pH, electrical conductivity (EC), total dissolved solids (TDS), Salinity, dissolved oxygen (DO) were checked by Water Analysis Kit (make: NPC363D, accuracy ±3%). Total hardness, calcium, magnesium were measured by titremetric method in the laboratory adapting standard methods (APHA, 2012)[11]. Heavy metals such as nickel and chromium were analysed using atomic absorption spectrophotometer (make: ECIL, AAS-4141).

2.4 Electrocoagulation Procedure

Electrocoagulation technique was employed for the treatment and removal of hardness from groundwater. Experiments were performed to investigate the effect of the parameters such as current density and electrolysis time. The removal efficiency was measured in terms of hardness with time and current density as variables. The schematic diagram of electrocoagulation cell is shown in Fig 1. The values of various operating parameters of batch electrocoagulation are given in Table 2. The batch experiments were performed using a 250 mL glass beaker for water sample 4 which has highest TDS and hardness. Aluminium sheets with dimensions of 12.5 cm × 2.5 cm × 0.3 cm were used as anode and cathode. The electrodes were dipped up to 5 cm in the sample and the effective area of the electrodes in the solution was 28.75 cm^2. The electrodes were connected to a DC power supply (make: Kitheley 2231A) providing (0-30 V and 0-3 Amp). The sample was stirred in the beaker by the magnetic stirrer (make: Labman) to maintain uniform concentration. After completion of the electrolysis time, the treated sample was allowed to settle for two hours. After settling, the sludge was separated and supernatant liquid was analysed. The removal efficiency (RE) of hardness and calcium were calculated using the following equation 4:

$$RE(\%) = \frac{C_o - C_i}{C_o} \times 100 \quad (4)$$

Where C_o and C_i are initial and final values of parameter of the sample in mg/L respectively.

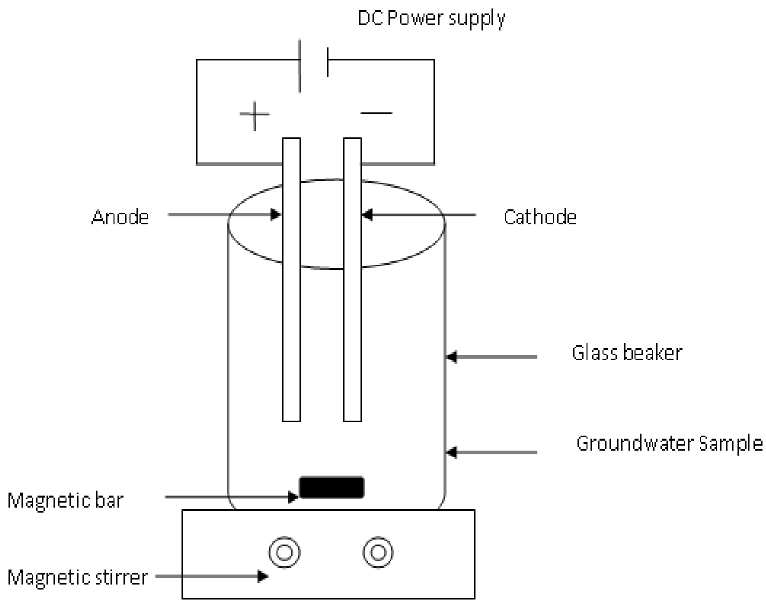

Figure 1. Schematic diagram of electrocoagulation cell

Table 2. Values of Various Operating Parameters for Batch Electrocoagulation

Parameter	Value
pH	7.36
Electrode distance (cm)	1
Agitation speed (rpm)	300
Electrolysis time (min)	30-150
Current (Amp)	0.5-0.75
Current density (Amp/cm^2)	0.0173-0.0347

III. RESULTS AND DISCUSSION

3.1 Sample characterisation

To assess water quality five samples were collected and analysed from different locations of Dwarka and nearby areas, New Delhi. The results of various parameters analysed are shown in Table 3.

Table 3. Characteristics of groundwater samples

Parameter	Estimated Values				
	Sample: 1	Sample:2	Sample:3	Sample:4	Sample:5
pH	7.16	7.54	7.98	7.36	7.38
Salinity(mg/l)	5360	5180	1879	9330	4910
TDS(mg/l)	3520	3450	1255	6220	3100
Total hardness(mg/l)	2073.33	1166.66	520	3900	1446
Calcium(mg/l)	320.64	232.46	66.53	961.92	240.43
Magnesium(mg/l)	316.74	141.31	86.25	365.47	206.12
Nickel(mg/l)	Nil	Nil	Nil	Nil	Nil
Chromium(mg/l)	Nil	Nil	Nil	Nil	Nil

By analysis and comparison of groundwater samples being collected with the BIS water specifications (IS: 10500) [12] given in Table 4, it was concluded that the quality of water was unfit for drinking purpose because of high TDS and hardness and henceforth needs treatment before use.

Table 4. Indian Standards for Drinking Water (BIS)

Parameter	Indian Standards Desired –Permissible limit(all in mg/l except pH)
pH of the sample	6.5-8.5
TDS	500-2000
Total hardness	300-600
Calcium	75-250
Magnesium	30-100
Nickel	0.02
Chromium	0.05

3.2 Effect of electrolysis time on hardness removal

For design of continuous process, electrolysis time is very important parameter. Hence in present work experiments were conducted to study effect of electrolysis time of hardness removal efficiency. The results are shown in Fig. 2 at electrode distance (1cm), agitation speed (300 rpm), pH (7.36) and initial hardness of 3900mg/l. It was noticed that the hardness removal efficiency increased with electrolysis time. Fig. 2 shows that at 30 min, current 0.5 Amp, the removal efficiency was 30% and at 150 min removal efficiency was 56.41%. At 30 min, current 0.75 Amp, the removal efficiency was 30.77% and at 150 min removal efficiency was 58.97%.

3.3 Effect of electrolysis time on Calcium removal

Calcium is one of the major constituent of hardness. Hence study was carried for Calcium removal. Results are shown in Fig. 3 at electrode distance (1cm), agitation speed (300 rpm), pH (7.36), initial hardness of 3900mg/l. Results indicate that with time calcium removal efficiency increases upto approx 120 minutes and after wards increase in calcium removal efficiency was negligible for present experimental conditions.

3.4 Effect of electrolysis time on TDS removal

TDS is first parameter to assess water quality and refers to total dissolved solids in water. In drinking water these solids are mainly inorganic salts. In present study effect of electrolysis time was studied on TDS removal for water sample no 4. The results are shown in Fig. 4. Figure shows that as time increases, TDS of water decreases. At end of 150 min. TDS of water was reduced to 5180 and 4150 ppm at 0.5 amp and 0.75 amp respectively.

3.5 Effect of current density on TDS removal

In electro coagulation current play an important role on rate of TDS removal. Hence its effect on TDS removal was studied and results are given in Fig. 5. Figure shows that as current increase TDS of treated water decreases. This may be due to precipitation of divalent and trivalent salt precipitation followed by coagulation due to increased production of aluminium hydroxide in solution.

3.6 Effect of current density on hardness removal

Current density is the most important parameters to control rate of reaction in electrocoagulation processes. By increasing the current density, speed and efficiency of removal process, energy and electrode consumption, the amount of produced sludge and operating costs increase while the reaction time decreases [3]. Thus effect of current density was studied on hardness removal efficiency. Results are shown in Fig 6.

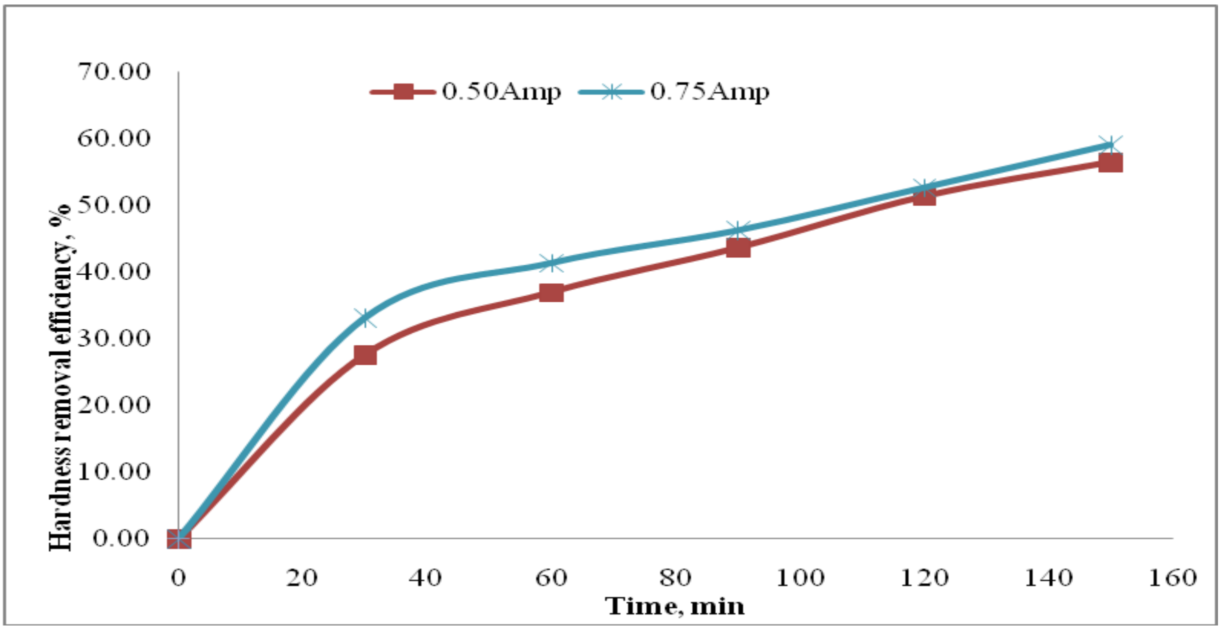

Figure 2. Effect of time on hardness removal

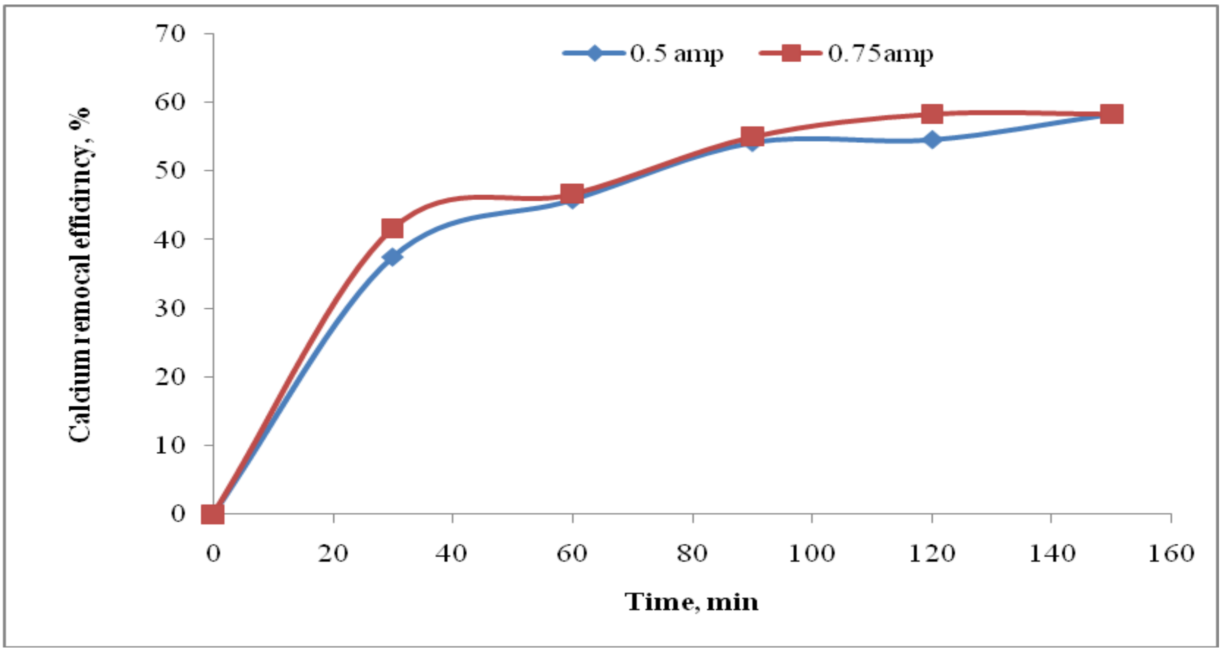

Figure 3. Effect of time on calcium removal

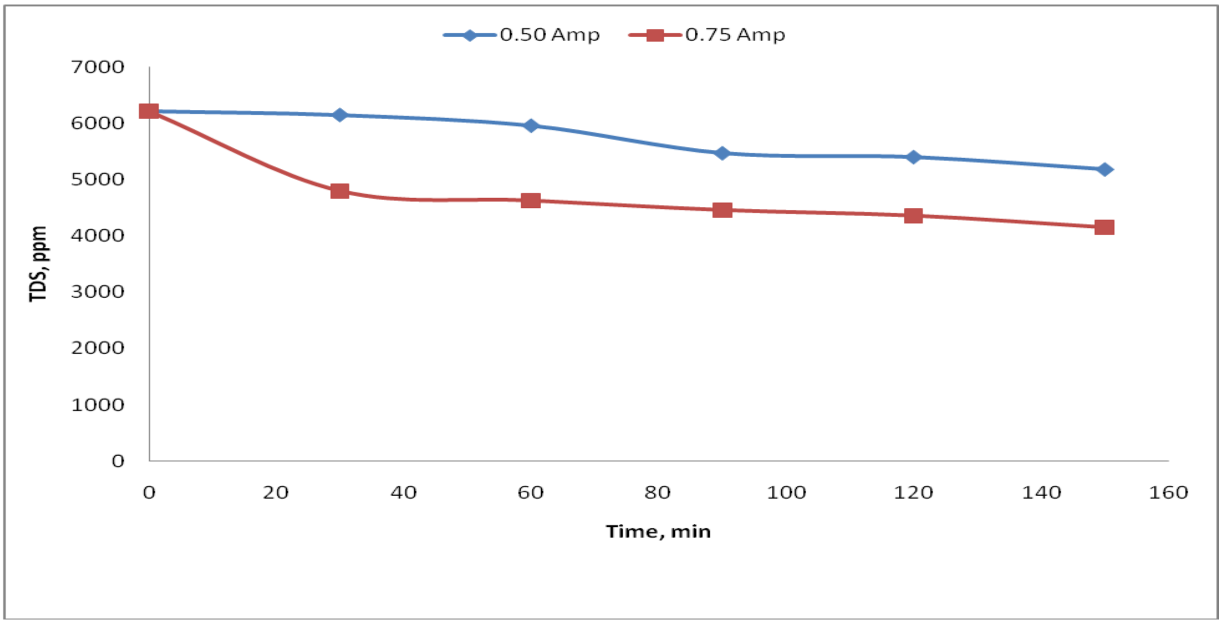

Figure 4. Effect of time on TDS removal

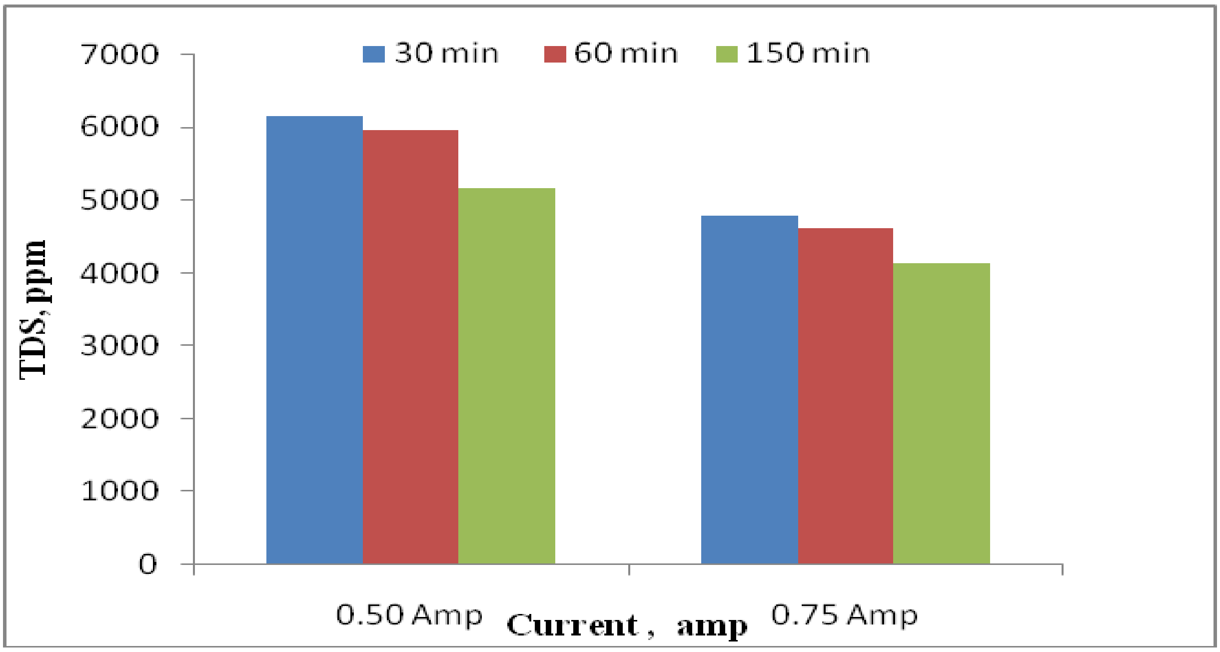

Figure 5. Effect of current on TDS removal

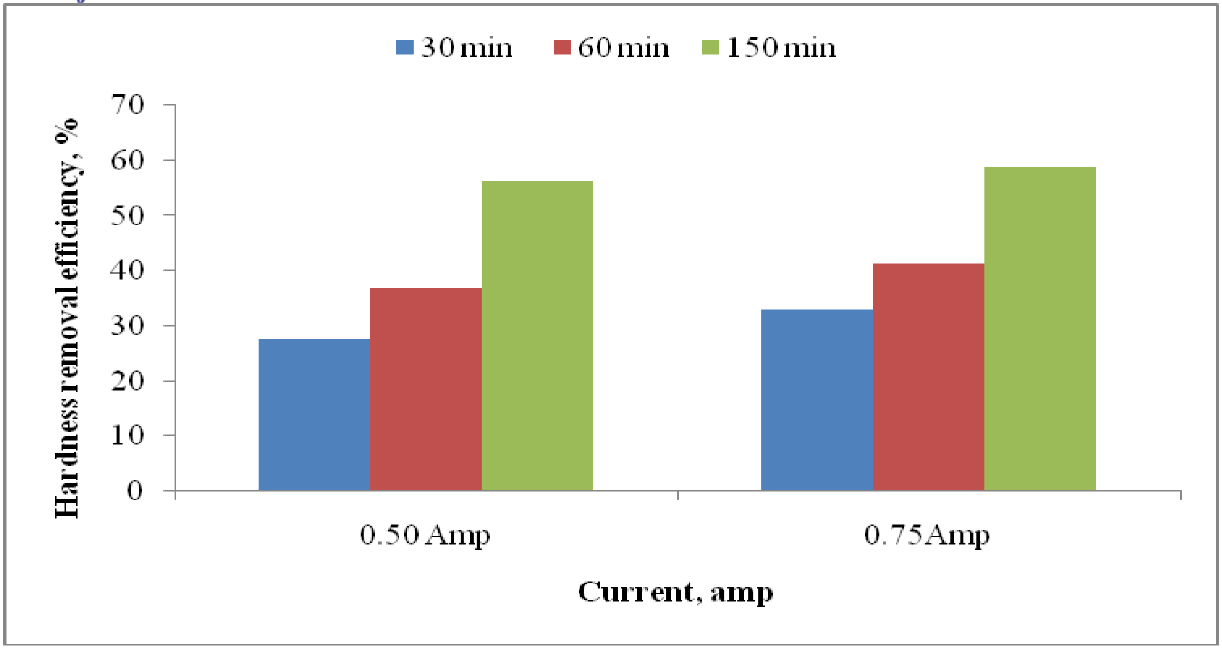

Figure 6. Effect of current on hardness removal

IV. CONCLUSION

The effect of current density on hardness removal and calcium removal by electrocoagulation from groundwater was studied. Results show that both hardness and calcium removal was affected by current density and time intervals. The maximum removal efficiency of 58.97% was obtained at an electrolysis time of 2.5 h at 5V and 0.75A. These results indicate that electrocoagulation process using aluminium electrodes can be effective in removing water hardness. But before its exploitation at commercial scale effect of other parameters like pH, potential difference, temperature etc. should be studied.

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