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REMOVAL OF FLUORIDE IN GROUND WATER BY ELECTROCOAGULATION METHOD

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Abstract: Groundwater is considered to be vast resource of Indian sub-continent**.** From several years, Ground water has b exploited for domestic, agriculture and other uses like industries etc. Due to unplanned industrialization, urbanization has led to the untreated waste contamination for ground water. The level of the fluoride content is rapidly increasing in ground water due to certain expedition. The current study presents the adaptive method named electro-coagulation which helps in the removal of the fluoride from the water. From the research, it was studied that the complete removal of the fluoride from ground water possible to 99.5%.

The purpose of this paper was to understand how the electro-coagulation method has been an effective and cheap method for the fluoride removal in ground water. The approach was to assemble the fundamental equations of the electro-coagulation in electrolysis of the ground water. Exceeding the level of fluoride content gave rise to skeletal flurosis in the human body. The parameters that are undertaken are concentration of the fluoride, distance between the electrodes and pH and applied voltage where constituent of fluoride removed from the groundwater is examined in the study. It has been observed that at concentration of 1, 5, 10 mg/L of fluoride solution were prepared by mixing proper amount of sodium fluoride with tap water. At pH 5.5 the effective results are obtained and revealed that the removal capacity of the fluoride through electrodes that are kept at distance of 1 cm can obtained an effective results.

Keywords **– Electrocoagulation, groundwater, cost-effective treatment, Fluoride removal.**

I. INTRODUCTION

Fluoride is one of the most essential elements to the human body. It has been observed the consumption of the fluoride in the water should not exceed above 1.5mg/L. This leads to fluorosis problem in the human being. It has undertaken the range of the semi-arid area and source where the ground water is the only source for drinking water. Fluoride is encountered as important geochemical deposits in Indian sub-continents. There are different channels through which natural fluoride pollution occurs in the environment. It has been examine that the discharge of the wastewater from the industries would lead to heavy contribution in the water reserves especially in ground water. According to Central Pollution Control Board of India, maximum number of the fluoride constituent is directed from industrial wastewater which is around 15mg/l.

Fluoride removal from the contamination from the groundwater has been reluctantly done by using various processes such as adsorption, reverse osmosis, chemical precipitation and Nalgonda technique, ion-exchange and electro-coagulation. Each and every method has their operational importance and constraints.

Electrocoagulation is the method which utilizes wash water treatment and other processed water through radio frequency diathermy or electrolysis of short wave. This method has the ability to remove the contaminants from the water which are more difficult to remove by filtration or chemical treatment systems. A typical electro-coagulation unit consists of electrochemical cell which has been connected metal electrodes and gaining power from DC supply. The only difference observed in the electro-coagulation method is that they generate coagulant from the electrochemical dissolution at anode. Further, the sacrificial anode is however made up of aluminum metal where the aluminum hydroxide flocs are produced. However, the negative charged fluoride ions and precipitated out in the form of sludge.

II. LITERATURE REVIEW

According to Guzaman et al (2016), the electro-coagulation is the process where the aluminum is used as sacrificial substance at anode. However, it requires continuous filter press reactor to which the collection of the groundwater is done through the depth of the 320 m in the region of the Mexico. It has been observed that the arsenic range value in the 43 mg/L has involved 2.5 mg/L of fluoride and sulfate to around 89.6 mg/l whereas as the other particles requires the different volumes. Henceforth, the EC was performed in order to gain the standard product at the current densities of 4, 5 and 6 mA/ Cm^2. It has presented the flow velocities to which the fluoride concentration has remarkably manage to have the arsenate component. The standards of the WHO for the CF are less than 1.5 mg/l. It presents that the pH7.6 and conductivity 993 would involve the 1 mg/l hypochlorite of arsenate which manages fluoride concentration in the experimentation. The spectrometric analysis is carried out with aluminum flocs being indicated with the silicate barrels. The Arsenate removal might include the adsorption of the aluminum flocs to which the hydroxyl group can aggregative perform the EC method. It has been obtained that the EC is

best in terms of obtaining the results through which at density 4 and conductivity 1.82 the electrolytic consumption of the energy has reached to 0.34 KWh.

As per Sandoval et al (2014), the fluoride removal has been an effective configuration for the drinking water. The electrocoagulation method leads to utilization of the aluminum anodes. It has been observed that the FTIR analysis, EDA-X and SEM equipments help in providing the information that flocs are slightly present in the water in the form of fluoride. The electro-coagulation leads to the removal of the 10 to 1 mg/l on the density of 4-6 m/Acm2. The 0.37kW has been provided in order to flow the rates of 0.91- 1.82 cm/s ratio of the fluoride content in the water. It has been favored that the massive generation of the electrolytic gases is disfavored with the fluoride content in the water at j>7 mA/cm2. The investigation to the fluoride content has been undertaken place in the synthetic drinking water where the 10mg/L is the constituent value and inclusion of the sodium sulphate to around 0.5 g/L has managed the Fluoride measures in the water. The conductivity ratio reached to 410 µS/Cm direct that the electro-coagulation has sacrificial anode. It has managed the EC test to quantify as per the WHO norms. The SEM, EDA-X and other analysis has been performed.

Khatibikamal et al (2010) has stated that electrocoagulation is the best process for the removal of fluoride content in the groundwater as well as for the industrial wastewater it has been originated from Steel industries that TTE electrocoagulation process utilizes aluminium electrodes which help in the removal of the fluoride content there are different aspects of operating the electrocoagulation process they are hydraulic retention time number of the aluminium plates between anode and cathode however the effects of different operating conditions such as temperature pH voltage has been successfully helpful in removing the efficiencies that were investigated the experimental results that are shown has been in effective in increasing the concentration levels of the of HRT system but on the other hand decreasing the fluoride content groundwater the increase has been noted down within the five minutes and the changes for seen a negligible. therefore the HRT that is the hydraulic retention time is considered to be only 5 minutes it requires a constant voltage and temperature in the systems in order to carry out the whole process the pH value decreases from 6.9 to 4.6 in the first 10 minutes and later on adding to the value to the removal of the fluoride content the pH is in effluent. so that it can be variably important than affects the fluoride removal significantly the optimal range has been recorded as the process of defluoridation which can be achieved. Other hands for the increasing number of the plates between the anode and cathode has been recorded to be a bipolar system. it does not significantly remove the fluoride but added value to it. It is also known as second Kinetic model equation which indicates the absorption system to obey the Kinetic analysis.

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III. MECHANISM OF ELECTROCOAGULATION

The electrochemical technique might provide the variety of the unwanted dissolved particles where the suspended matter can effectively managed with the aqueous solution. The process requires a steady pass through which the anode and cathode rods might have some liquidated range. The aluminum electrodes include the solution at anode and hydrogen gas at cathode. It has also dissolved the AI anodes to the aluminum species where the coagulating agent combines to provide the pollutants of the large size flocs. The suspended particles might collide as the tank might have some colloidal range to which the surface of the water can be entertained.

The pollutants basically present the electro-coagulation and electro-flotation measures in order to gain the electrolytic cells over cathode and anode respective to the features. The dynamic shift in the process provides the dominant of the process. The sacrificial electrode might include the different material where the anode can gain the interactive range to which the electro-coagulation can occurred..

IV. DETAILS FOR STUDY

The present study involves the comparative analysis of the electrocoagulation method with other methods such as distillation, membrane filtration process and other method through which fluoride can be removed. It can certainly addressed on the ground water and conversion of the drinking water to certain extent.

BENEFITS OF ELECTRO COAGULATION

Electro-coagulation aka Radio frequency diathermy or short wave electrolysis has been tremendously used to remove the solids, total petroleum hydrocarbons and other features. It can help in reclaiming the water for reuse and harvesting the valuable by products. It has been coal fueled power plant which provides the following benefits:

- The chemical coagulation is an efficient process but the sludge creation requires continuous effort in the filtration of the material. It also requires labor-intensive work which would affect the health complications. But the No filters requirement in the Electro-coagulation helps in providing the free access to the process as well as no additives and can be suspended by the solids, oils, fats and heavy metals.
- In Mechanical Filtration, it has been observed that the particles are greater than 30µm and suspended solids. However, in electro-coagulation, the size of the suspended or dissolved particles is not fixing and can provide the information for any size material.

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V. RESEARCH METHODOLOGY

The ground water is collected through the nearby reservoir and has been used in the study. The local distillery water and tap water is involved in the range of ground water. The study focuses on the removal of the fluoride content from the water and makes it sound more pure. The chemical practices direct on the analytical reagent grade where the stainless steel can manage to use the electrode material. The local supplies and procured sheets have been directed in order to carry out the testing. The flat bottomed flask utilized in the reactor has been made up of the acrylic glass has been included in the study;

3.1Population and Sample

The present study involves the chemicals including the Sodium Fluoride (NaF) which is an analytical grade for the study. The variables that are utilized to meet the concentration range from 1-10 mg/l. This can provide the solution which is prepared through mixing the right amount of the sodium fluoride with ground water. The pH is initially the solution adjusted with the 5, 7 and 9 range. It has involved the sodium hydroxide (1N) as the solution experimentation along with this sodium hydroxide (1N) has been utilized in order to perform the batch reactor. The internal size of the cell is basically presented as follows:

REACTOR CHARACTERISTICS: Make Acrylic (organic glass), Reactor type: Batch mode, Dimensions (L x W x H)(cm): 13cm_13cm _ 13.8cm, Volume (dm3): 1.5, Electrode gap (mm):15, Stirring mechanism magnetic bar: 62.9 m2
Power supply direct current (DC), Voltage range (V) = 10-49 V, Current range (A)= 1- 4 A m-2.

3.2 Data and Sources of Data

For this study secondary data has been collected. From the website Google Scholar and trusted websites which are accountable for gathering the data from 2009 to 2019. It can certainly help in examining the changes over the period of time. It has been addressed that the information that is gathered help in evaluating the current research statistics.

3.3 Theoretical framework

The active coagulation practices involve various liquid wastes. It has remark that the convenient soluble anodes such as stainless steel might help in presenting the electrochemical cell which manages the experiment of the reactor. The dissolution of the electrode might deter the results. Further, it has added the value to which the neutralization of the electrode takes place. Henceforth, the negative charges might be affluent on the electrochemical cell where the yield metal ions respectively dissolve.

As per this, the metal ions are likely to be present in the hydroxyl ions and cathode presents the hydroxide ions. It has mainly covered the flocks which are usually formed and separated from the substance through filtration method or decantation. It is basically assumed that the method which is utilized is likely to be based on the density. The range of the principles which is affluent and providing the minimal treatment to the products and services are electro coagulation and chemical coagulation. The cations which are present in the substance can help in gaining the coalescene of science and managing the environmental colloidal particles with the specific process.

In case, the electro-coagulation method is applied in the study, the matter of fact would represent the coagulant with in situ and dissolve the anode with the coagulants. But in case of Chemical coagulation, the dissolution of the aluminum or iron salts is obtained instead of the coagulants.

Another feature that can be focused in the electro-coagulation method is that the presence of the steel electrodes which helps in significant removal of COD from the ground water if present. However, the content of the nitrogen, phosphorous and other vital minerals and components has been explored which needs to be eliminated from the ground water if present in abundance.

The electrolytic dissolution of Al anodes in water produces aqueous

At Anode: Al (a) Al3++ 3e-

At Cathode: 2H2O+2e- H2+2OH-

The experiential Coagulants involve the aggregated particles to which the adsorption of the dissolved contaminants is basically preferred. The destabilization mechanism has involved the contaminant to which the particulate suspension can be effectively charge.

3.4Experimental method

This section elaborates the settling characteristics that arises due to the adoption of the electrocoagulation and managing the practices through which the sludge from the water can be strongly achieved.

3.4.1 Settling Characteristics

The precipitation occurred with the Electro-coagulation method directs on the removal of the sludge from the water. The variant depends on the pH and other characteristics. The settling characteristics present the participate removal and settling of the sludge strongly on PH. it has been evident that the industrial operations need to be efficiently managing combustion of the equipments which can be settled down quickly. It has been found that the characteristics have been performed in a 500 ml measuring cylinder and the data of the interface has been supertnant. The measuring cylinder and the data that has been the interface between the super tenants in the sludge timings were noted. The inclusion of the Kynch theory has been utilized to analyze the settling process of the populated particles. The key assumptions that are utilized by the theory are:-

- ✓ They do not take the effect of the wall in a serious consideration
- ✓ Uniform way of particle concentration was assumed
- ✓ Differences in the shape size and compositions have led to the no differential settling of particles in the study
- ✓ Concentrations of the participant removal were undertaken into initial parameters at it rises towards the bottom
- ✓ Pitfall of the sediments has been found to have a certain impact on the local concentration of the particles as well as their velocities
- ✓ the concentration of the approaches has reached the sedimentation velocity which tends to be zero in an initial phase and limiting their values

3.4.2 Operating parameter

They consider various parameters for operations that can be successfully discussed in the subsections. they are:-

3.4.2.1Electrode thickness

This thickness can be potentially measured by thicker and wider electrodes which will be minimized by potential drop and also having a long life easy backwash operations through ECR.

3.4.3 Electrode Spacing/gap

During the process of electrolysis, the solutions that are combined utilized are more concentrated because of the cathode. it has certainly raised the different abilities of the science that are present in the agitation in bulk solutions. the inter-electrode gaps are partially filled with the gases and have been recorded to increase the electrical resistance during the electrolysis process it certainly increases the electrical resistance due to the agitation of the reactor content. Corrugated electrodes have helped in raising the electrolytic gas release. it is quite effective that the open complications and vertical parallel plates arrangements have proven to be an important aspect in the flotation of precipitated sludge. ECR has been controlling the electrolyte spacing by analyzing the effect on the size of the reactor. SA/V ratio has

helped in the energy consumption and significantly estimating the cost and the treatment levels of the electro fluoride content since the ohmic potential drop is proportional to the inter-electrode spacing it has certainly reduce the spacing to a certain extent. it has also helped in energy consumption and narrowing the space-enhancing the mass transfer characteristics in the project. The plan electrode gas has been responsible for practicality and the field consumptions it has favorable III manage the situations and also synthetic wastewater and real wastewaters electrode spacing assumptions. They are found to be 3 mm in 8 mm respectively. With a range of working load cell voltages, it is favorable to understand the settle able flocs. It certainly examines the turbulence level and lowers it to a certain extent to require the frequent polarity reversals it has raised the planning of the high SV reactors. The turbulence returns out to be important as it initiates the mass transfer within the ECR. Inter-electrode spacing has been turned out to be 10mm as essential for ECT of Black liquor from pulp and paper mill wastewater. Similarly, it can be applied to the groundwater for the removal of fluoride content in it. If the spacing turns out to be less than 10 mm then the swirling velocities will lead to affect the pollutants instead of removing them.

3.4.4. Cell potential

The cell voltage is defined as the potential difference between the two identical metallic terminals which are usually attached to the anode and cathode of the cell. The floor of the current through ECR is recorded to comprise several components that help in the associations of electrochemical processes which are orchid usually by the potential difference between the cathode and anode electrode. The overall voltage that has been recorded helps in the hyper activations of the results and slowness of the electrode reactions. the key activation factors that have been recorded helps in elevating the temperatures and lessening to a certain extent for the pressure which reduces activation overvoltage. in electrolysis, the cell voltages increase the current density which helps in meeting the desired results. On the other hand, the settleable properties are recorded to be important as the enhancement of the electric voltage can be degraded. During the groundwater treatment, the chances to enhance the degradation effects of the fluoride contain might cross the voltage of fewer than 3 volts but to a certain extent, it is found to be more than 4 volts. at the high-level voltage, the consumption of the current utilized by the oxygen evolution and other reactions is an achievement in the EC cell. It has developed many strategies that have successfully led to the desired results for the project conducted. Some of them are:-

- ✓ Reduction of the equilibrium cell potential
- ✓ catalytic reactions to maximize or minimize the water potential electrodes
- ✓ Operating current reductions to manage their overpotential and ohmic loss
- ✓ Conductive electrodes membranes and electrolyte efficiently work together

3.4.5 Limiting current

To meet the demand of the electrochemical reactions the anode is combusted into the organics anomaly characterized as the current efficiency which is called flux.

$$\phi = \frac{ICE}{ICE_i}$$

Where ICE is the instantaneous current efficiency gained from the anode. ICE_i instantaneous current efficiency will be obtained while conducting the ideal current efficiency.

$$I_{Lim} = 4sFK_M C \quad (2.8.2$$

$$I_{Lim} = 4sFK_m\ COD = 4sFK_m\ COD_0\ [1-X] \quad (2.8.3)$$

The key range of the anodic surfaces can be remarkably meet with the mass transfer and number of the exchanged groups to which the electro-oxidation reaction. It can include the Faraday's law which has been adding features to the business proportion and entertaining the values of the electrocombustion process. It can also decrease the COD concentration in the wastewater and fluoride precipitate in the ground water. Henceforth, the setting the pH and current limit setting helps to raise the water into a drinkable unit.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

Table 4.1: Descriptive Statics

	Percentage of Removal By:				
Constituents	Electro-coagulation	Membrane Filtration processes	Sedimentation	Ion-exchange	Distillation
TSS	95 to 99%	95 to 99%	50 to 70%	80 to 90%	95 to 99%
BOD	50 to 98%	50 to 80%	25 to 40%	40 to 65%	50 to 90%
Bacteria	95 to 99.99%	80 to 90%	25 to 75%	35 to 55%	88 to 95%

Table 4.1 Comparative analysis of the methods better for removal of fluoride . The statistical measure of the percentage of removal of the constituents present TSS to around 95 to 99% by electrocoagulation, similar with the membrane filtration method. But the sedimentation and ion-exchange and distillation accounts on lesser reduction of fluoride in the ground water.

The key aspects of EC process come from the word electrolysis which has efficiently managed to gain the support of electrolytes. It is efficiently manages to enhance the conductivity of the across medium and managing the current of electrode that is positive and moves to cathode and negative ions to anode. It is certainly raise the anions are oxidized and cations are reduced. The electrochemical mechanism is a quite complex process which has possibly followed the mechanism of electro-coagulation and electro flotation. it has established the suspended emulsified or dissolved contaminates by introducing an electric current into aqueous medium that parallel metal electrodes connected in a monopolar or bi polar or dipolar range helps in carrying out the process. The different methods of the treatment of the fluoride in groundwater however the electrocoagulation is considered to be an eco-friendly and economical viable process that has been used in the study.

In the current process the treatment of the groundwater through the electrocoagulation process has been the prominent role remove the fluoride containing the water. it has significant impact on gaining the advantages or benefit through which operations become is an automations, slash formations high velocity demonstrations and no chemical additives involvement has raised the efficiency level.

Consequently the chances of the electrocoagulation process presents the cathode and anode reactions for removing the fluoride by utilisation of the aluminum electrodes are demonstrated as follows

At the anode:

$$Al \rightarrow Al^{+3} + 3e \quad \ldots\ldots (1)$$

At the cathode:

$$2H_2O + 2e \rightarrow H_2 + 2OH \quad \ldots\ldots (2)$$

It can efficiently manage the high rate to the secondary reactions which helps in evaluating the oxygen level

$$2H_2O \rightarrow O_2 + 4H^+ + 4e \quad \ldots\ldots (3)$$

The key range of the Aluminum level by electrolytic range to anode which can be foreseen through equation 1 and presenting the hydrolysis of the monomeric species are according to the following sequence:

$$Al^{3+} + H_2O \text{----------} Al(OH)^{2+} + H^+ \quad \ldots\ldots (3)$$

$$Al(OH)^{2+} + H_2O \text{----------} Al(OH)^{2+} + H^+ \quad \ldots\ldots (4)$$

$$Al(OH)^{2+} + H_2O \text{----------} Al(OH)_3(s) + H^+ \quad \ldots\ldots (5)$$

$$Al(OH)_3 + xF \text{--} Al(OH)_{3-x}F_x + xOH^- \quad \ldots\ldots (6)$$

4.2 Effect of fluoride concentration in ground water

An important parameter that has decided the removal of the pollutants in the initial concentration of the groundwater has been included in the study. So, right removal of fluoride efficiency decrease with increase in the concentration level of the water for the same applied. It is an evident due to the amount of the metal oxides rocks formed might be insufficient in removal of the fluoride molecules at the higher initial fluoride concentration. The concentrations initially the fluoride molecule readily populated in the velocity of the sacrificial anode. But as the treatment time process increased diffusion resistance to the movement to the surface of the anode reduce the rate of the electro-coagulation.

Initial Conc. (ppm)	pH		Conductivity (µm)		TDS (ppm)		Turbidity (NTU)		Resistivity (Ohm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
5	7	8.02	1812	1234.56	1002	654	1.93	0.82	0.623	1.102
10	7	8.11	1683	997.6	589	537	0.89	0.45	0.745	0.886
15	7	8.58	1173	778.12	668	423	1.23	0.93	0.704	2.011
20	7	8.67	1419	745.37	478	289	1.34	0.76	0.756	1.291
25	7	8.68	1301	613.9	447	245	2.13	0.73	1.034	1.543

Table 2: effect of fluoride concentration in ground water

4.3 Effect of reaction time and current applied

The production rate of the coagulants and the growth rate of the flocs are certainly dependent on the applied current. The prime factor are also considered as the operational parameters which needs to be control and helpful in determining the mechanism of the electro-coagulation process.

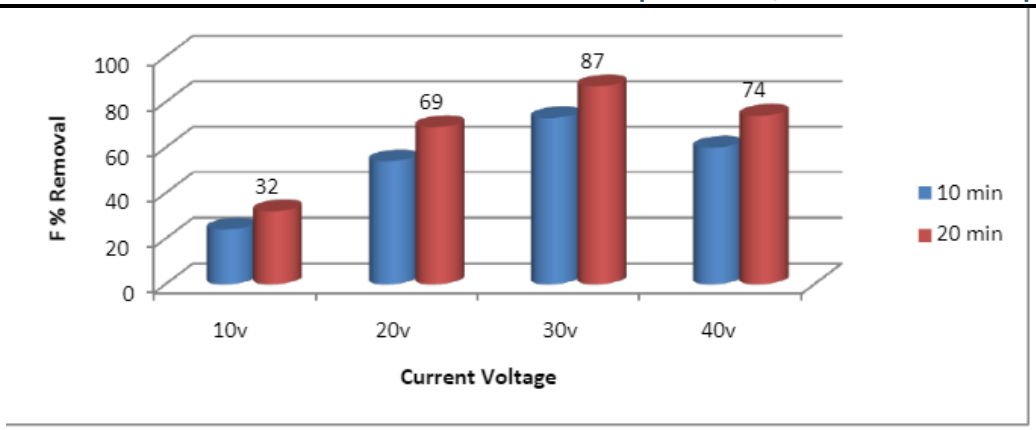
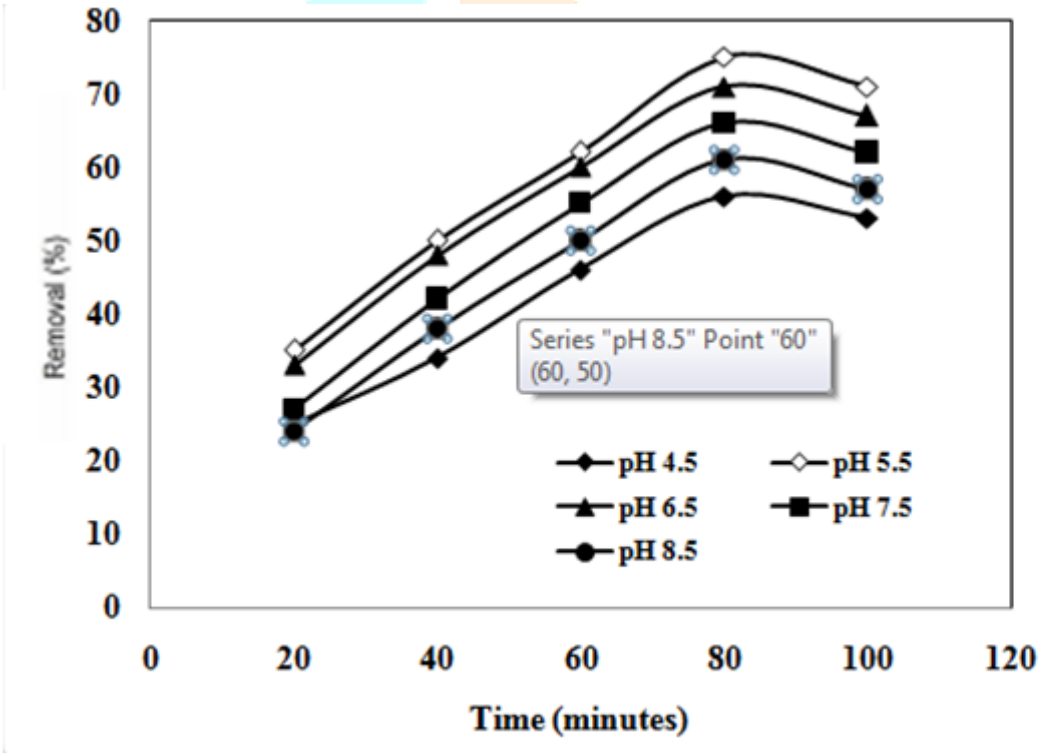


Figure 1: %F removal at applied current statistical

4.4 Effect of pH

The different results of PH and color reductions varying pH are thanks to quality and quantity of hydroxide ions generated at particular pH. Variety of components like proteins, Carbohydrates, lignin are present in ground water. they need various functional groups with electric charge that react with Fe and its charged hydroxides, e.g. FeOH2+ etc. the amount of electrode loss, formation of Fe2+, Fe3+, Fe(OH)2, Fe(OH)3, and monomeric and polymeric hydroxide species varied with pH. At pH< 8, protons within the solution get reduced to H2. Consequently, the proportion of the hydroxide ions produced is a smaller amount, resulting in lower pH removal efficiency. Maximum PH reduction 75% was obtained at pH and 5.53 Ampere current. The pH solutions are efficiently handled on the following parameters.



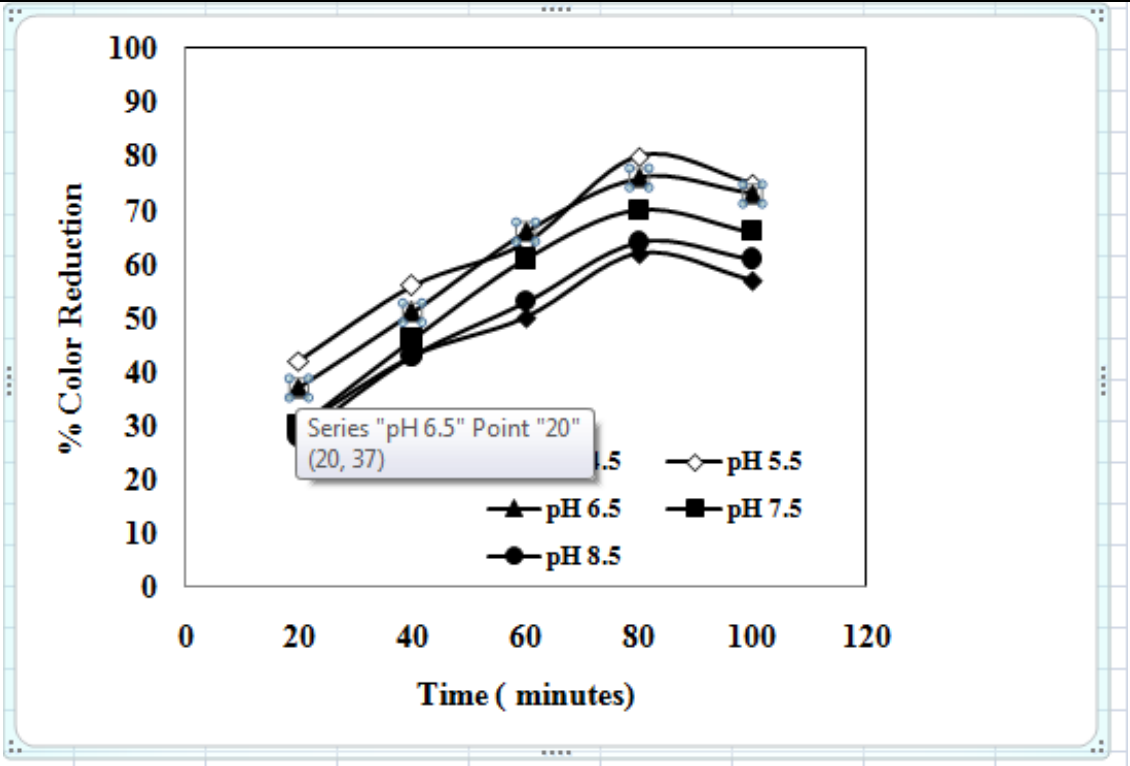


Figure: effect of pH on ground water by electrocoagulation method using SS304 electrode, pH= 8913 mg/dm3.

4.5 comparative Rates of Methods for fluoride removal

	Chemical Precipitation	**Activated Alumina**	**R.O.**	**Electro coagulation**
Efficiency	Lowest	Low	Very High	**Very High (Almost 100%)**
Treatment Cost	10 – 12	10 - 14	60	**8-10**
Treatment Time	2 – 4 Hrs	Very Slow flow	Continuous	**90 min**
Water Recovery	High	High	50-60%	**Very High**
Regeneration/ Maintenance	Not Required	Regeneration + Backwash	Required	**Not Required**
Man Power	Requires manpower		Skilled Manpower	**Unskilled Person**

Sludge	Maximum	High	High	**Lowest**
Disinfection	No	No	Yes	**YES**

V. CONCLUSION

The electro-coagulation (EC) process proved to be an efficient method for the removal of fluoride from ground water. The experimental process that's accounted will help in providing the reduction details of the percent of the fluoride compound within the water and also provide crystal clear water for drinking. However, it's predicted that complete removal isn't possible. Electrocoagulation technology has achieved grade of applicability and hence examined as potential defluoridation technology.

It is highly compared with traditional flocculation–coagulation, electrocoagulation has the advantage of removing the tiniest colloidal particles and comparatively low amount of residue generation. In spite of getting numerous advantages, EC has some drawbacks like the periodic replacement of sacrificial anodes. Also it requires a minimum conductivity reckoning on reactor design that limits its use with water containing low dissolved solids.

Additionally the control of residual aluminium, technical and economical optimization of the method per the standard of water being treated must be taken into considerations. Although large numbers of studies are available in literature further studies are required to elucidate the potential and limitations of the method. so as to proportion the strategy, the longer term work should be focused on investigating the influence of assorted operational parameters including duration, energy consumption and initial fluoride concentration in addition as interference from factors like calcium ions in effluents

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