

Reduction of Fluoride from Groundwater by Electrocoagulation using Iron Electrode

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Abstract: Fluoride contamination in groundwater is a major public health concern of the present time. Fluoride is essential for good health of teeth and bones but if it is found in excess quantity in water than permissible limit (1.5 mg/L) then it will be harmful for teeth and bones. Sometimes it causes kidney failure or death. Fluoride level in India ranges from 0.5 mg/l to 48mg/l. AP, Rajasthan and Gujrat are the states that are severely affected by excess fluoride. In Maharashtra 19 Districts are affected by excess fluoride problem which indicates the need of Fluoride detection and its reduction. For defluoridation Electrocoagulation (EC) in batch reactor setup was prepared. A 15x15x 15 cm glass reactor of capacity about 2 litre volumes as EC glass reactor and four iron electrodes of size 14.5x 2.5x 0.1 cm were used. Effects of varying applied voltage, initial concentration and initial pH on fluoride removal efficiencies were evaluated. Iron electrodes were used in EC for 3 hours for reduction of 20mg/l of fluoride from synthetic sample at 5V, 10V, 15V, 20V, & 25V. The percentage removal of excess fluoride from 20mg/L was 93% at 25V for contact period of 180 min. The maximum percentage fluoride reduction was observed in the pH range of 7.65 – 8.10. The same experiment will be done with aluminium electrodes also.

Keywords: Fluoride, Defluoridation, Electrocoagulation, pH, Voltage, Iron electrode.

1. INTRODUCTION

Water is essential natural resource for sustaining life and environment which we have always thought to be available in abundance and free gift of nature. Uses of water include household, agriculture, recreational and environmental activities in rural and urban areas. Quality and quantity of water are being challenged by increasing pollution in India. Today, India is relying increasingly on groundwater for both, irrigation and drinking water requirements, unlike in the past, when surface water was the main source of water [1]. Numbers of elements are already mixed in surface and groundwater such as chlorine, iron, sulphur, fluoride, nitrogen, arsenic and etc. Common pollutants in groundwater include fluoride and nitrate which are of mainly natural and anthropogenic origins, respectively. It occurs mainly in the form of chemical compounds such as sodium fluoride or hydrogen fluoride, which are present in minerals fluorospar, fluorapatite, sallaite, topaz and cryolite [4].

Fluoride has beneficial effects on teeth at low concentrations in drinking-water, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. These range from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases. Crippling skeletal fluorosis is a significant cause of morbidity in a number of regions of the world. Fluoride is known to occur at elevated concentrations in a number of parts of the world and in such circumstances can have, and often has, a significant adverse impact on public health and well-being [8].

World Health Organization (WHO) recommends Fluoride is essential for good health of teeth and bones but if it is found in excess quantity in water than permissible limit (1.5 mg/L) then it will be harmful for teeth and bones. Sometimes it causes kidney failure or death. Fluoride level in India ranges from 0.5 mg/l to 48mg/l. More than 200 districts in 20 states of our country are affected by fluoride pollution in drinking water. AP, Rajasthan and Gujrat are the states that are severely affected by excess fluoride [5]. In Maharashtra 19 Districts are affected by excess fluoride problem and Nanded is one of them. Nanded belongs to the drought prone areas of Marathwada region. All 16 Tehsils of Nanded District are affected by excess fluoride content in Groundwater, among these some of the villages of Bhokar, Dharmabad, Umari Tehsils has fluoride concentration in range of 5 mg/l to 47 mg/l (URL: <http://indiawater.gov.in>) [6][7].

Several specific techniques for the removal of these contaminants are available and include adsorption, chemical precipitation, coagulation, ion exchange and electrocoagulation [3]. Electrocoagulation is one possible innovative, cheap, decentralized and effective treatment strategy to purify ground water for human consumption.

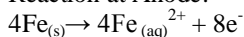
Electro coagulation

The process of destabilizing and oxidizing suspended, dissolved contaminants in an aqueous medium by introducing an electric current into the medium is known as

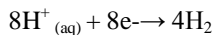
Electrocoagulation. Due to the passage of current, the anode dissolves during EC, and is often termed the 'sacrificial' electrode. It is generally made of metals like Al or Fe. Dissolution of the anode results in the formation of metal cations. These metal cations form metal hydroxide species, similar to coagulant salts like alum and ferric chloride in conventional chemical coagulation. These cations and other charged metal hydroxide species can bring about neutralization of negatively charged particles and compounds. Once they are neutralized, the particles can bind together to form flocs resulting in contaminant removal [1].

In the EC process, no chemical coagulants or flocculants are added, for reducing the amount of sludge. Gas bubbles that are produced during electrolysis can carry the contaminant to the top of the solution where it can be easily concentrated, collected and removed. EC is controlled electrically and has no moving parts, and therefore, maintenance is low. The EC process includes coagulation, electroflotation and electro-oxidation in a single unit.

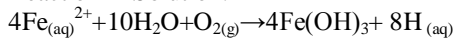
Reaction at Anode:



Reaction at Cathode:



Reaction in Solution:



The objective of the present study was to evaluate the extent of fluoride removal from drinking water using EC in batch reactors under different operating conditions. Effects of varying applied voltage and initial concentration on fluoride removal efficiency were evaluated. In all experiments, changes in pH, conductivity, turbidity, DO and F concentration were monitored.

2. MATERIALS AND METHODS

Chemical and Water samples

Fluoride (NaF, >99%) was purchased and kept in the dark place, until use. Deionised water was used to prepare all solutions used in this study, and the solution pH was adjusted by the addition of HCl and NaOH. Tap water contaminated with fluoride was prepared by the addition of NaF to original tap water to obtain final F concentration of 20 mg/L. Fluoride solutions were prepared synthetically in laboratory using distilled water and sodium fluoride.

Experimental Setup

A glass reactor of capacity about 2 litre volume used as the EC batch reactor of dimensions 15cm length, 15cm width and 15cm height (Fig. 1). Four iron electrodes of size 14.5cm x 2.5cm x 0.1cm with immersion depth of 9 cm and inter-electrode distance of 3 cm were used. These electrodes were

connected to a transformer of capacity 0 to 28 volts and 0 to 3.5 Amperes, which was used for converting AC current to DC current. Experiments were conducted at applied voltages of 5V, 10V, 15V, 20V, and 25V. Turbidity, Conductivity, pH, DO and Fluoride were monitored during each experiment. The supernatant at the top of the reactor was collected after every 30 min. intervals and stored in test tubes. All supernatant samples were filtered using filter paper.

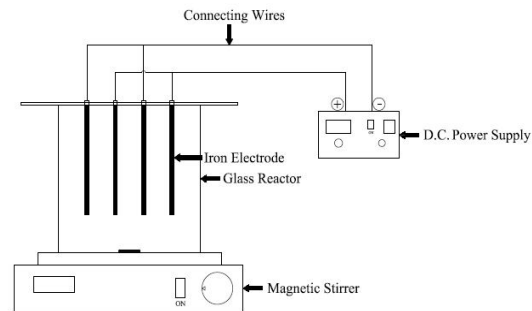


Figure 1: EC batch reactor and experimental setup for the removal of fluoride.

Sampling

Current was passed for 180 minutes with continuous stirring using a magnetic stirrer at 150 rpm for adequate mixing. Samples were collected from the top of the reactor at intervals of 30, 60, 90, 120, 150 and 180 min.

Analytical methods

Only analytical grade reagents were used in the study and distilled water was used to prepare stock solutions. A stock solution of 20mg/L sodium fluoride was prepared in distilled water and added to the EC glass reactor as required. Samples were analyzed for pH, turbidity, conductivity, DO and fluoride.

pH, Conductivity, Turbidity and DO

pH of all solutions was monitored using a digital pH meter [Multiparameter Eutech PCD 650] calibrated with a buffer solution of pH 7 & pH 4. Conductivity was measured using a digital conductivity meter [HACH SensION EC7]. Digital Turbidity meter [Turbidimeter Hach 2100N] was used to measure turbidity. DO was measured using digital DO meter [HACH HQ 40d].

Fluoride analysis

Fluoride concentration was measured using a Spectrophotometer [Hach DR5000], maximum concentration that can be measured is 2.0 mg/L hence dilution process was used to measure the concentration of Fluoride.

3. RESULTS AND DISCUSSION

The effects of operating parameters on fluoride removal efficiency were examined in EC batch experiments: applied voltage, initial concentration and initial pH. Besides fluoride, pH, turbidity, conductivity, and DO were monitored during each experiment.

Effect of Applied Voltage

The rate of coagulant generation and therefore, removal of contaminant is dependent mainly on the current passing through the electrochemical cell. Therefore, the voltage applied to the electrodes was kept constant for each experiment. The effect of applied voltage on fluoride removal efficiencies was studied for the same initial concentration of fluoride 20mg/L and the results are shown in Fig. 2.

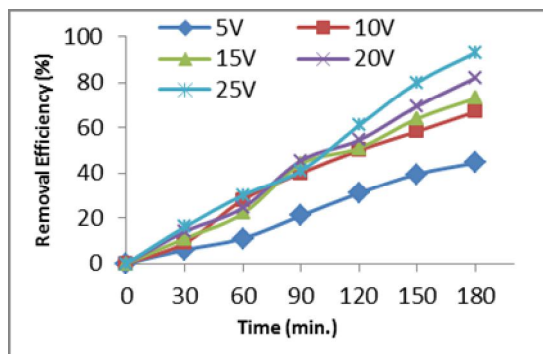


Figure 2: Effect of applied voltage on % removal of fluoride with time.

The applied potential was increased from 5V to 25V, percent fluoride removal increased from 61% to 91%. Dissolution of the metal anode results in the formation of cationic coagulating ions like metal oxides and hydroxides and the amount of iron hydroxide available in solution to form complexes and precipitate the ions increases [2].

Conductivity

Conductivity varied throughout the experiment. The highest conductivity (1.336mS/cm) was observed after 90 min. at 5 V and the lowest (0.398 mS/cm) was observed after 120 min. at 25 V in the supernatant shown in Fig. 3. It is likely that the amount of coagulant ions produced was highest at 25 V resulting in the highest amount of floc formation and settling of floc. Floc settling and removal from supernatant can lead to decrease in ion concentration in the supernatant. This would result in lower conductivity at higher applied voltages as compared to lower applied voltages.

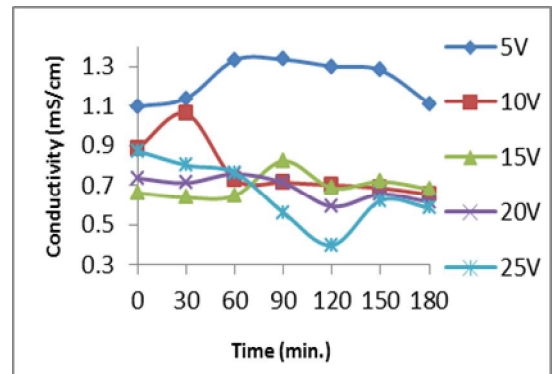


Figure 3: Variation in conductivity for different applied voltages.

Turbidity

Turbidity of the water was measured after filtration at every 30 min. time intervals during the experiment and was found to increase steadily with time at all applied voltages as shown in Fig. 4. With time, coagulant production increases leading to increased floc. Hence, final turbidity increased with increase in applied voltage, the lowest turbidity was observed 5.2 NTU at 10V and highest turbidity was 9.2 NTU at 25V.

pH

pH was monitored in the EC reactor at different voltages during the each experiment and the results are shown in Fig 5. The initial pH varied from 7.06 to 7.86 and the final pH varied from 10.97 to 7.87 for 5V to 25V respectively

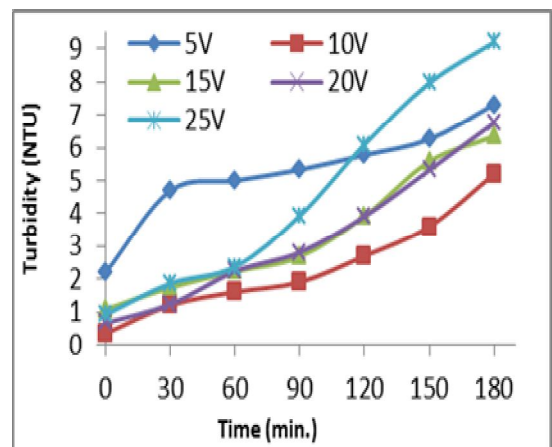


Figure 4: Change in turbidity for different applied voltages.

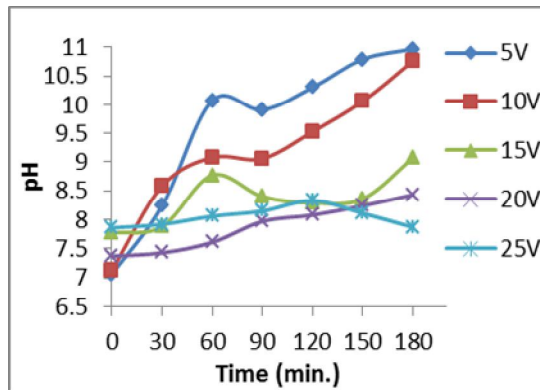


Figure 5: Change in pH for different applied voltages.

Change in pH and results of fluoride removal efficiency as per different applied voltages are shown in Table 1.

4. CONCLUSION

Fluoride is most common ground water contaminants of natural origin in India. Fluoride reduction was achieved in this study through electrocoagulation and filtration. Filtration was necessary after EC to achieve acceptable water quality in terms of turbidity. In the batch studies, three operating parameters were evaluated: applied voltage, initial concentrations and initial pH.

Applied Voltage: On the standard lab condition fluoride reduction efficiency was increases with increase in voltage in EC batch reactor for 20mg/L. In batch electrocoagulation reactor, maximum F reduction efficiency for 20mg/L was 93% at 25V.

pH: With respect to pH following observations are noticeable that (1) Irrespective of initial pH there was significant variation in pH during experimentation. (2) In batch electrocoagulation, the initial pH ranges from 6.50 to 7.40 changes water towards alkaline water. For all voltages, the maximum percentage fluoride reduction was observed in the pH range of 7.65 – 8.10. It is observed that a percentage fluoride reduction decreases beyond 90 min. for pH above 8.10.

Table 1: Variation in removal of Fluoride efficiency with varying pH at different voltages in EC batch reactor.

Applied Voltage (V)	Initial pH	Final pH	Change in pH	Initial concentration (mg/L)	Final Concentration (mg/L)	F Removal Efficiency (%)
5V	7.06	10.97	3.91	20	11.1	44.5
10V	7.13	10.76	3.63	20	6.6	67
15V	7.77	9.07	1.3	20	5.4	73
20V	7.37	8.43	1.06	20	3.6	82
25V	7.86	7.87	0.01	20	1.4	93

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