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Continuous Electrochemical Coagulation Study For Simultaneous Removal Of Arsenite And Fluoride From Drinking Water

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Abstract : *Continuous Electrochemical coagulation(CECC) studies was carried out for simultaneous removal of arsenite and fluoride from groundwater for optimal operating condition obtained from batch ECC studies for Fe_1-Fe_2-Fe_3-Fe_4(FFFF) and Fe_1-Fe_2-Al_3-Fe_4(FFAF)electrode arrangement. Results revealed, maximum removal effliciency of arsenite achieved for Fe_1-Fe_2-Fe_3-Fe_4(FFFF) with 16V, 4 iron electrodes(4E) for 45 min ET and removal of both arsenite and fluoride was achieved for Fe_1-Fe_2-Al_3-Fe_4(FFAF) electrode arrangements for 16V, 4E for 45 min ET for fixed arsenite and fluoride concentration of 1.6 mg/L and 12 mg/L respectively. The CECC studies investigated the effect of different flowrates 2,4 and 6 Lph in simultaneous removal of arsenite and fluoride from groundwater for Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4. Maximum As(III) and F^- concentration reduction occurred from its initial value for Fe_1-Fe_2-Al_3-Fe_4(FFAF) of CECC with effective carbon bed 22cm depth activated carbon column for 2Lph. The other drinking water quality parameters after CECC were well within the BIS drinking water quality standards. Thus, novelty of CECC studies reflected lesser the flowrate more simultaneous removal of arsenite and fluoride efficiency.*

Keywords *- arsenite, continuous electrochemical coagulation, flowrate, fluoride, simultaneous*

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I. INTRODUCTION

Groundwater represents one of the mean drinking water sources for most people around the world [1]. Long-term exposure to polluted water with arsenic and fluoride creates chronic health problems such as hyperpigmentation, and keratosis of hands and feet. It also causes bladder, lung, skin, kidney, liver, and prostate cancer [2]. Considering toxicity of arsenic and fluoride, World Health Organization (WHO) and U.S. Environmental Protection Agency have set maximum acceptable level of arsenic in drinking water at 10 mg/L and maximum acceptable level is 1.5 mg/ L for fluoride. Different technologies have been developed to decrease arsenic and fluoride concentrations in groundwater. Arsenic and fluoride both exist in the form of anion in water. Very recently in 2015, high arsenic and fluoride concentration has been reported in the groundwater of Rajnandgaon district of Chhattisgarh in India [3]. Hence, it is an urgent need to find a technology which can efficiently remove arsenite and fluoride both from groundwater.

Electrocoagulation is an emerging treatment technology which has been applied successfully to treat various contaminants and industrial wastewater. Electrocoagulation became a proven and effective method for water treatment. It represents a new alternative for treating water because of its high efficiency in removing large number of pollutants [4]. Electrochemical coagulation studies have been carried out previous by other researchers for arsenic and fluoride removal. Arsenic removal mechanism and reactor configuration is discussed [5], arsenic removal is high if EC is operated at liquid motion driving mode [6], combined Al-Fe electrode system in arsenic removal is reported [7] .EC has been employed to perform defluoridation [8]. Fluoride distribution in electrocoagulation defluoridation process discussed [9]. Considering the application of electrocoagulation process, the present research work is carried out.

Based on its simple operation, fast, selective, reproducible, economic and eco-friendly technology, the above authors have carried out previously the batch ECC studies for (i) arsenite removal using only iron electrodes for various applied cell voltages ranging from 6,8,12 and 16V for different electrode numbers 4,6 and 10 for initial arsenite conce ntrations ranging from 0.05 mg/L to 7 mg/L for 60 min electrolysis time(ET) and also (ii) experiments were carried out for simultaneous removal of arsenite and fluoride from groundwater for different aluminum and iron electrode placing position inside the reactor. The batch experimental results revealed that the maximum removal effliciency of arsenite achieved for Fe_1-Fe_2-Fe_3-Fe_4(FFFF) with 16V, 4 iron electrodes for 45 min ET and simultaneous removal of arsenite and fluoride was achieved for Fe_1-Fe_2-Al_3-Fe_4(FFAF) electrode arrangements for 16V, 4 electrode numbers for 45 min ET for fixed arsenite and fluoride concentration of 1.6 mg/L and 12 mg/L respectively. In this regard continuous ECC studies followed by adsorption column was performed for both Fe_1-Fe_2-Fe_3-Fe_4(FFFF) and Fe_1-Fe_2-Al_3-Fe_4(FFAF) electrode arrangement in the present research work.

The present research work was carried out to investigate the (i) effect of different flow rates such as 2, 4 and 6 Lph on simultaneous arsenite and fluoride removal (ii) Changes in water quality parameters after CECC and (iii) study on economic evaluation factors such as (i) electrode dissolution (ii)Sludge generation (iii)Energy consumption and (iv) operating cost.

II. Materials And Methods

2.1. Sample Preparation and Groundwater characterization: Groundwater samples were collected from nearby borewell and spiked with desired concentration of arsenite and fluoride for experimental purpose. The sample was analysed before and after CECC for other drinking water quality parameters as shown in Table. 1 and Table.2 using standard methods.

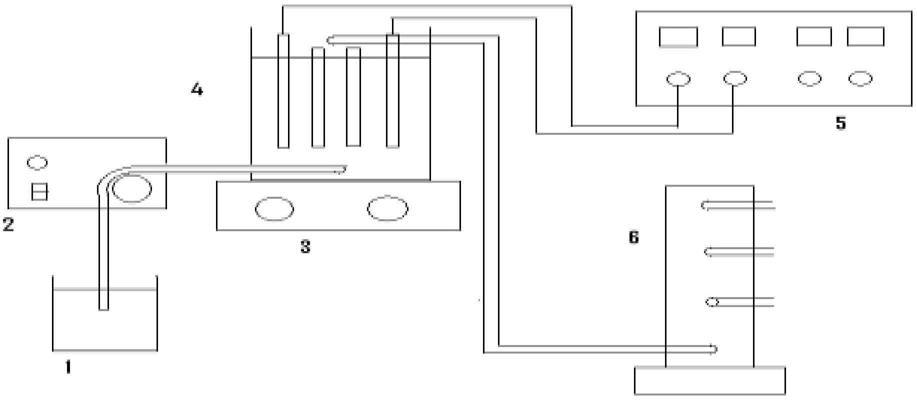
Table 1. Characterization of Groundwater before ECC

Sl. No	Parameter	Values	BIS (IS 10500-91, Revised 2003) Desirable limit
1	Temperature,℃	22-29	-
2	pH	7.52-7.73	6.5-8.5
3	Total Alkalinity as $CaCO_3$, mg/L	360-377	200
4	Conductivity, µS/cm	807-1075	300
5	Turbidity, NTU	0.29-1	5
6	Chloride, mg/L	70-91	250
7	Total Hardness as $CaCO_3$, mg/L	352-463	300
8	Calcium Hardness, mg/L	140-160	75
9	Magnesium Hardness, mg/L	212-253	30
10	Iron, mg/L	0.01-0.03	0.3
11	Sulphate, mg/L	34-46	200
12	Arsenic,mg/L	Nil	0.01
13	Total Dissolved Solids, mg/L	470-490	500

2.2. Reagents and Materials used: All chemicals used in the study were of analytical reagent (AR) grade obtained from Hi - Media laboratories Pvt. Ltd, Mumbai, India. The analysis of various physico-chemical water quality parameters were carried out using various equipments and instruments. pH was measured using pH meter (LI 127 Elico make). The electrical conductivity of water was measured using a digital conductivity meter (Systronics model 30/10FT YSI). Temperature variations recorded using a digital thermometer. Iron, nitrate, fluoride, sulphate and phosphate concentrations are determined using UV- spectrophotometer. Total hardness, total alkalinity and TDS was determined as per Standard Methods [10]. Aluminum and arsenic concentrations in the solution were determined using Inductively Coupled Plasma (ICP Horiba Jobin Yvon, France).

2.3. Experimental setup and Methodology: The carbon adsorption column serves as the polishing treatment, to remove residual turbidity in the post ECC water. The adsorption column used was made of acrylic glass. The GAC was washed with groundwater and sun dried. The column was filled with granular activated carbon (GAC) having an average particle size of 2-5 mm GAC with density packing control at exercised between the ports in the column. A thin layer of ~ 0.3 mm thick glass - wool was placed at the invert of the adsorption column before filling the column with GAC. Up-flow type column was chosen to achieve a complete mass transfer zone (MTZ) and to avoid short circuiting/cross flow shock/surges and cone formation.Continuous flow experiments followed batch ECC studies at different flowrates 2, 4 and 6 L/h using peristaltic pump. The treated samples were collected at 22 cm and 44 cm carbon bed depth at the exit ports. The column was filled with fresh dried GAC before each run without water.

Based on the optimum operating condition obtained from batch electrochemical coagulation process a Continuous ECC followed by adsorption column studies were carried out simultaneously in a batch - continuous convertible perplex electrochemical coagulation reactor (ECR) of 2L total capacity. The inlet to the ECR was connected to a peristaltic pump to pump arsenite and fluoride spiked groundwater from the feed tank into the ECC reactor. The outlet of the ECC reactor was connected to the inlet port of the GAC filled column at its base to operate in the upflow direction. The schematic arrangement is shown in Fig.1.



1. Spiked arsenite and fluoride groundwater; 2.Peristaltic pump; 3. Magnetic stirrer; 4.ECC Reactor; 5.DC power supply; 6. GAC Adsorption column.
Fig. 1 Schematic diagram of continuous ECC followed by adsorption column experimental set-up for removal of both arsenic and fluoride.

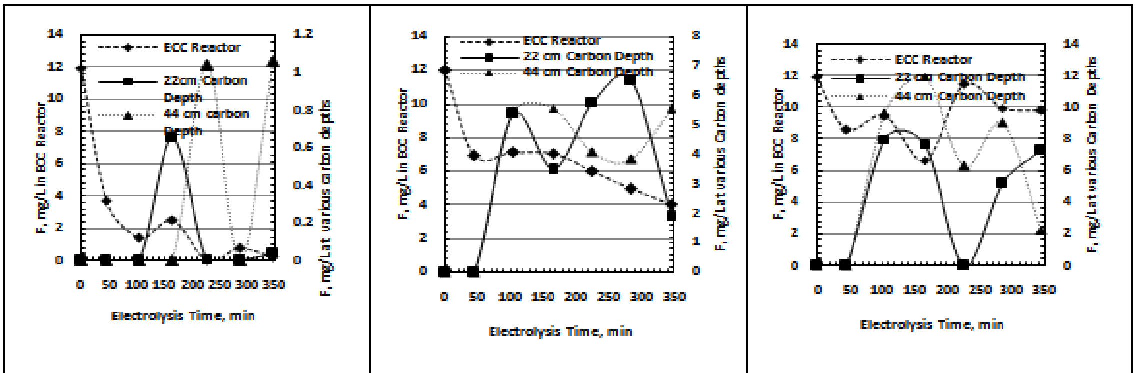
Once the ECR, column and pumping arrangements were set, batch ECC was initiated at the pre-set operating conditions which was obtained from first and second specific objective i.e., 16V, inter-electrode spacing 5mm, 4 electrodes (iron-iron-iron-iron+ iron-iron-aluminum-iron), $F_0^-: 12\ mg/L\ and\ As(III)_0: 2.54\ mg/L$ for 45 min of electrolysis. After 45min of batch ECC, the inlet and outlet taps of the ECR convertible were opened to allow untreated groundwater to flow into the ECR through a peristaltic pump pre-set at a particular flowrate. This time T_{45} marks the beginning of the partially treated water in the ECR that enters the adsorption column. As the water exits the column the samples were collected from each of the ports at carbon bed depths of 22 cm and 44 cm at regular time intervals of 0, 45 min, 1, 2, 3, 4 and 5 h. To record the continuous ECC treatment system, samples were collected from the (i) outlet of the ECC reactor entering the column and at different bed depths located at (ii) 22 cm and (iii) 44 cm of the column simultaneously. All continuous ECC experiments was carried out for a limited time duration of 5.45 h for flow rates of 2, 4 and 6 Lph for electrode arrangement of Fe_1-Fe_2-Al_3-Fe_4 and Fe_1-Fe_2-Fe_3-Fe_4 and analysed for residual arsenic, fluoride, iron and aluminum; this data helps determination of the carbon depth required to keep other water quality parameters well within drinking water quality parameters.

III. Results And Discussion

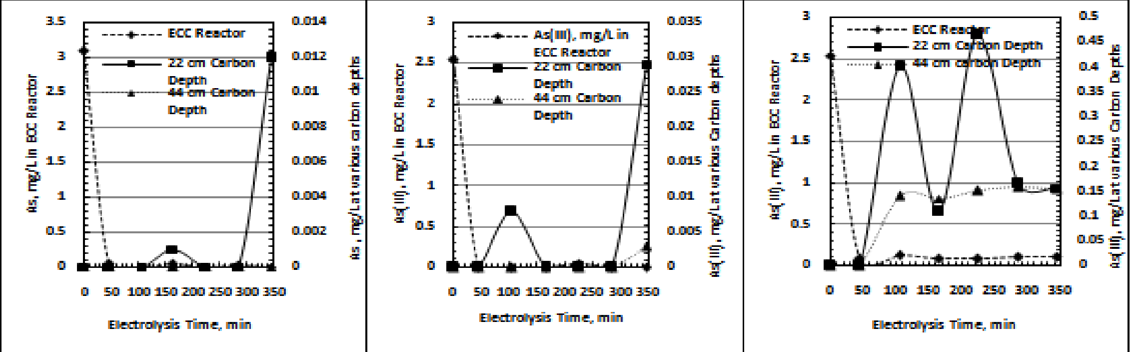
Continuous Electrochemical Coagulation (CECC) experiments was carried out using Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 electrode arrangements at optimum operating conditions determined in the batch studies. CECC was carried out for simultaneous arsenic and fluoride removal for various flow rates 2, 4 and 6 lph respectively using a peristaltic pump. The initial As (III) and F^- concentrations were 2.54 mg/L and 12 mg/L for a constant cell voltage of 16V set for a 5.45 h reaction time. The flow rates were maintained in the ECC reactor of 2L capacity with the outlet of the ECC reactor connected to the port of the carbon(granular activated carbon- GAC) filled adsorption column at its inverts. The post ECC treated water showed the presence of suspended micro-flocs as turbidity. GAC was chosen to remove turbidity particles and also traces of residual arsenic, fluoride, aluminum and iron ions.

3.1 Continuous ECC followed by adsorption for Fe_1-Fe_2-Al_3-Fe_4 for flowrates 2, 4 and 6 Lph

The curves in the Plot 2. AA^1, BB^1 and CC^1 shows variations in fluoride, As(III) concentration as a function of electrolysis time for the samples collected at the outlet of ECC reactor, at a length of carbon bed column of 22cm (Port1) and 44cm(Port2) at different flowrates of 2, 4 and 6 Lph for Fe_1-Fe_2-Al_3-Fe_4 electrode arrangement for $As(III)_0$ of 2.54 mg/L and F_0^- of 12mg/L respectively.



A. **FFAF – 2Lph** **B.** **FFAF – 4 Lph** **C.** **FFAF – 6 Lph**



A¹ FFAF-2Lph **B¹ FFAF-4Lph** **C¹ FFAF-6LPH**

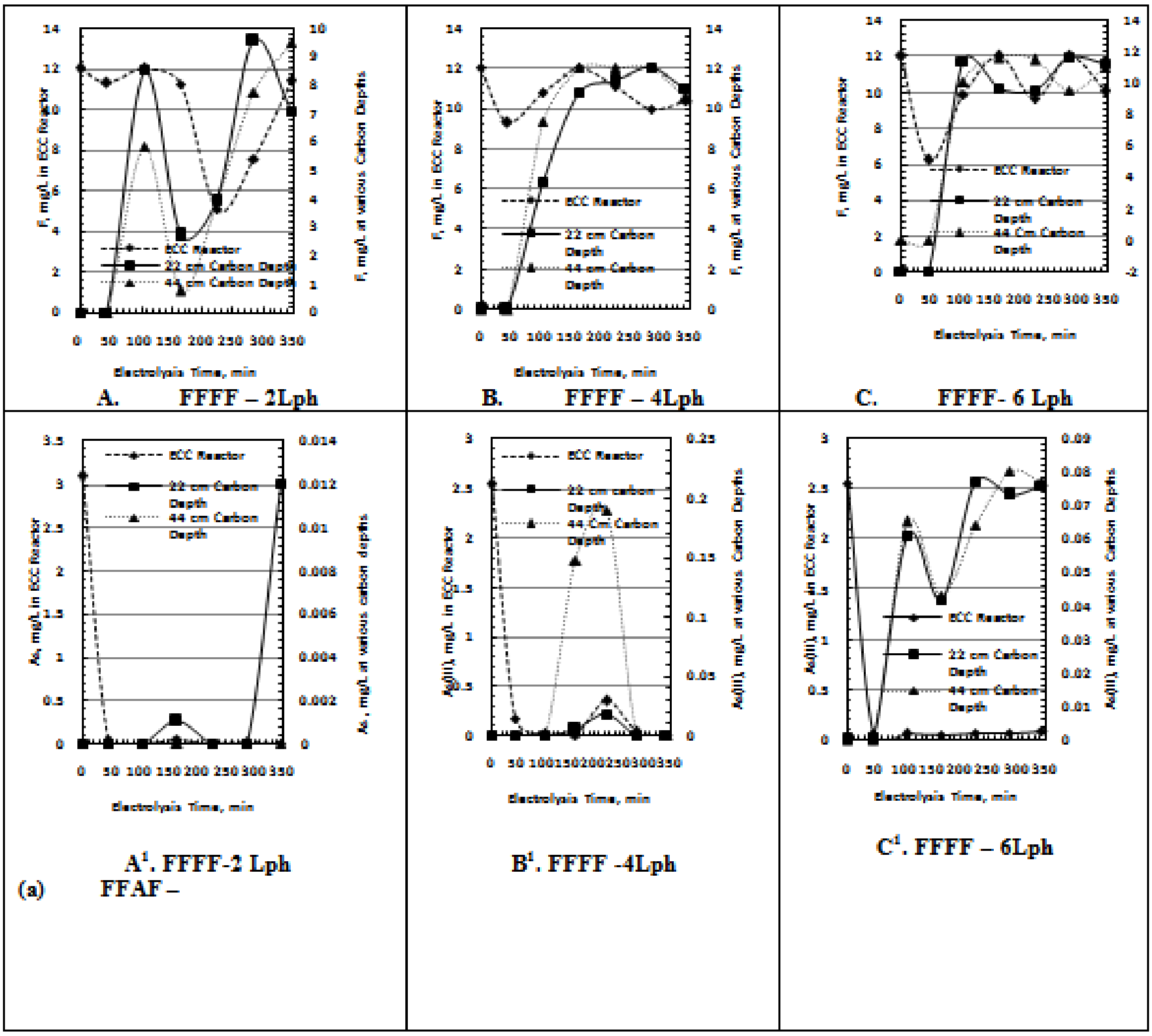
(a) **FFAF –**

FIG 2. Continuous study with operating condition: V: 16 Volts; As(III)$_0$: 2.54 mg/L; F^- : 12 mg/L; N: 4E ; Electrode arrangement: Fe$_1$-Fe$_2$-Al$_3$-Fe$_4$; interelectrode space: 5mm; Carbon Bed Depths: 22cm and 44cm; Flowrates (a) 2 L/h, 4L/h and 6L/h; ET: 350 min as a function of Reaction time on simultaneous removal of Fluoride and Arsenite in ECC reactor and at various carbon depths.

After 45 min of batch ECC the F^-, As (III) concentration reduced from 12 to 3.7 mg/L and 2.54 to 0.048 mg/L respectively. Iron concentration in the reactor increased from 0 to 0.042 mg/L and aluminum concentration remained at 0 mg/L with a small increase in pH of water from 7.21 to 7.38 and a decrease in conductivity from 978 to 676 µS/cm and an increase in temperature by 1°C. At this time, the outlet and inlet taps of the ECC reactor were opened with flow rates kept constant throughout the CECC time. In Plot AA^1, at the end of 5.45 h CECC fluoride, As(III), iron, aluminum concentrations, pH, temperature and conductivity were 0.26 mg/L, 0.0 mg/L, 0.0 mg/L, 0.608 mg/L, 8.61, 28.0°C and 623 µS/cm at the exit of ECC reactor; at port 1 and 2, these parameter values were 0.04 mg/L, 0.0 mg/L, 0.0 mg/L, 0.668 mg/L, 8.37, 27.0°C and 359 µS/cm and 1.06 mg/L, 0.0 mg/L, 0.0 mg/L, 0.387 mg/L, 8.03, 27.0°C and 621 µS/cm respectively. Re-entrainment of As(III), F^-occurred because of desorption from locally saturated carbon blocks and also because of ions re-entering the solution from the scum atop the ECR. Because of this effect, the scum layer was skimmed off manually. Throughout the treatment period of 5.45h CECC, fluoride, arsenic, iron and aluminum concentrations were well within the BIS drinking water quality standards. For flow rate of 4Lph with the same operating procedures as set for 2Lph. In Plot 2. BB^1,at the end of 5.45 h the fluoride, As(III), iron, aluminum, pH, temperature and conductivity in ECC reactor was 4.04 mg/L, 0.0 mg/L, 0.005 mg/L, 0.003 mg/L, 7.62, 26.5°C and 397 µS/cm and 0.89 mg/L, 0.029 mg/L, 21.6 mg/L, 4.45 mg/L, 7.62, 27.0°C and 359 µS/cm at Port 1 and 5.55 mg/L, 0.003 mg/L, 0.003 mg/L, 0.56mg/L, 8.03, 26.2°C and 383 µS/cm at Port 2. Thus, it was observed that fluoride, aluminum and iron concentrations from each port were exceeding BIS standards after 5.45h treatment. The curves in the Plot 2.CC^1 shows the variations in fluoride, As(III), iron, aluminum, pH, temperature and conductivity as a function of reaction time with constant flowrate of 6Lph.At the end of 5.45 h the fluoride, As(III), iron, aluminum, pH, temperature and conductivity concentration in ECC reactor were 9.86 mg/L, 0.11 mg/L, 0.0 mg/L, 0.0 mg/L, 7.43, 26.5°C and 370 µS/cm and 7.34 mg/L, 0.156 mg/L, 0.0 mg/L, 0.0 mg/L, 7.46, 26.0°C and 389 µS/cm at Port 1 . Similarly, the same parameters were 2.26 mg/L, 0.154 mg/L, 0.0 mg/L, 0.0 mg/L, 7.43, 26.0°C and 411 µS/cm at Port 2. The concentration of fluoride and arsenic was observed to exceed the BIS standards and iron and aluminum concentration was 0.0 mg/L from 0-5.45h of ECC indicating that the amount of active coagulants liberated in not sufficient to remove the target contaminant.

3.2 Continuous ECC followed by adsorption for Fe_1-Fe_2-Fe_3-Fe_4 for flowrates 2, 4 and 6 Lph

Fig 3 AA[1],BB[1] and CC[1] shows the simultaneous removal of arsenic and fluoride for varying flow rate of 2,4 and 6 lph for 5.45 h for Fe_1-Fe_2-Fe_3-Fe_4 electrode arrangement. The study was carried out in the similar way as Fe_1-Fe_2-Al_3-Fe_4 experiment. The curves in the plots AA[1], after 5.45 h the fluoride, As(III), iron, aluminum, pH, temperature and conductivity concentrations in ECC reactor were 11.37 mg/L, 0.0 mg/L, 0.204 mg/L, 0.0 mg/L, 9.01, 29.0°C and 289 µS/cm and 7.09 mg/L, 0.0 mg/L, 0.296 mg/L, 0.0 mg/L, 7.1, 26.0°C and 260 µS/cm at Port 1 and 9.45 mg/L, 0.0 mg/L, 0.684 mg/L, 0.0 mg/L, 7.19, 26.5°C and 297 µS/cm at Port 2. Only As(III) removal was achieved but fluoride removal was not satisfactory. The aluminum concentration was 0.0 mg/L due to absence of aluminum electrodes. Iron concentration was exceeding the BIS drinking water standards and the pH of the solution turned alkaline making it not fit for drinking. For flowrate of 4 Lph, in plot BB[1] at the end of 5.45 h the fluoride, As(III), iron, aluminum, pH, temperature and conductivity concentrations in ECC reactor were 4.04 mg/L, 0.0 mg/L, 0.0 mg/L, 0.0 mg/L, 8.75, 27°C and 387 µS/cm and 1.89 mg/L, 0.0 mg/L, 0.0 mg/L, 0.0 mg/L, 8.56, 26.5°C and 376 µS/cm at Port 1 and 5.55 mg/L, 0.0 mg/L, 0.0 mg/L, 0.0 mg/L, 8.43, 26.6°C and 370 µS/cm at Port 2. Throughout the ECC continuous run the fluoride, arsenic and iron concentration were exceeding the BIS drinking water standards. For flowrate of 6 Lph as shown in plots CC[1] after 5.45 h the fluoride, As(III), iron, aluminum, pH, temperature and conductivity concentrations in ECC reactor was 10.03 mg/L, 0.087 mg/L, 0.0 mg/L, 0.0 mg/L, 7.36, 26.5°C and 406 µS/cm and 11.58 mg/L, 0.076 mg/L, 0.0 mg/L, 0.0 mg/L, 7.69, 26.5°C and 436 µS/cm at Port 1 and 11.0 mg/L, 0.077mg/L, 0.0 mg/L, 0.0 mg/L, 8.18, 26°C and 458 µS/cm at Port 2. Fluoride and arsenic concentration were not reduced to the prescribed BIS drinking water standards. From the above set of experiments, it was concluded that, with increase in flow rate the As(III) and fluoride removal efficiency decreased.



A. **FFFF – 2Lph**

B. **FFFF – 4Lph**

C. **FFFF- 6 Lph**

A[1]. FFFF-2 Lph

(a) **FFAF –**

B[1]. FFFF -4Lph

C[1]. FFFF – 6Lph

FIG 3. Continuous study with operating condition: V: 16 Volts; As(III)0: 2.54 mg/L; F^- :12 mg/L; N: 4E ; Electrode arrangement: Fe_1-Fe_2-Fe_3-Fe_4; interelectrode space: 5mm; Carbon Bed Depths: 22cm & 44cm; Flowrates (a) 2 L/h, 4L/h and 6L/h; ET: 350 min as a function of Reaction time on simultaneous removal of Fluoride and Arsenite in ECC reactor and at various carbon depths.

The decrease in the flow rate increases the residence contact time of the contaminants in water with the ECC floc thereby initiating the removal process. The efficiency of Fe_1-Fe_2-Fe_3-Fe_4 for fluoride removal was found unsatisfactory as only arsenic removal could be achieved. Whereas, the removal efficiency of fluoride and arsenic with Fe_1-Fe_2-Al_3-Fe_4 electrode combinations was found to be satisfactory with other operating parameters such as 16V, 4E, Fe_1-Fe_2-Al_3-Fe_4. A higher hydraulic retention time in the reactor and carbon column at lower flowrates favoured the removal rate of arsenite and fluoride.

IV. Variation in Water Quality Parameters after Continuous ECC followed by adsorption column

Continuous ECC followed by adsorption study was performed for Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 arrangement for 2, 4 and 6 Lph for 5.45 h. The variations in water quality parameters that occurred during ECC treatment at different flow rates is tabulated in Table 2.

Table 2. Variation in Water Quality Parameters at different flowrates

SL.No.	Water Quality parameters	BIS		Fe_1-Fe_2-Fe_3-Fe_4			Fe_1-Fe_2-Al_3-Fe_4		
		DL	PL	2 lph	4 lph	6 lph	2 lph	4 lph	6 lph
1	pH	6.5-8.5	No relaxation	7.19	8.4	8.18	7.76	8.7	8.9
2	Temperature, °C	-	-	26	26.6	26	23.5	23.5	23.5
3	Conductivity, µS/cm	300 µS/cm		297	370	458	260	810	860
4	TDS, mg/L	500	2000	260	300	350	300	400	490
5	Turbidity, NTU	5	10	0.25	0.56	0.2	1.2	2	3.4
6	Total Alkalinity, mg/L	200	600	152	800	600	240	290	320
7	Chloride, mg/L	250	1000	58.7	62	78	72	73	73.9
8	Sulphate, mg/L	200	400	35.6	97	0	13	11	12
9	Total hardness as $CaCO_3$, mg/L	300	600	160	240	80	176	176	176
10	Calcium hardness as $CaCO_3$, mg/L	75	200	120	200	0	88	88	88
11	Magnesium hardness as $CaCO_3$, mg/L	30	100	40	40	80	88	88	88
12	Iron, mg/L	0.3	1	0.47	0.18	0	0.26	0.34	0.48
13	Fluoride, mg/L	1	1.5	9.45	10.53	11	1.4	1.9	2.10
14	Aluminum, mg/L	0.03	0.2	0	0	0	0	0	0
15	Arsenic, mg/L	0.01	0.05	0.081	0	0	0	0	0

DL- Desirable Limit; PL –Permissible Limit

From the above table, it may be observed for Fe1-Fe_2-Al_3-Fe_4 - 2 Lph, all the water quality parameters were well within the drinking water standards prescribed by BIS. It was observed that a reduction in chloride values were attained after passing through the carbon column, ascribed to the chlorinated organics formed during, ECC treatment. Turbidity removal was also achieved after passing through the activated filter column, following the rule stated by S.V Yakovlev about Post-ECC**.** It shows that, choosing activated carbon as an advanced tertiary treatment method after ECC treatment proves effective. The change in color before and after ECC treatment and after filtration through filter column is shown in Fig.4.

Fig. 4 Groundwater sample before ECC, after ECC and after passing through carbon filter column

4.1 Effect of flowrate on electrode dissolution with respect to placing position in the ECR

A major advantage of accepting ECC in treatment is the electrode consumption. Fig. 5 illustrates the effect of flowrate on electrode dissolution (ED) for simultaneous removal of arsenite and fluoride to meet the drinking water quality standards.

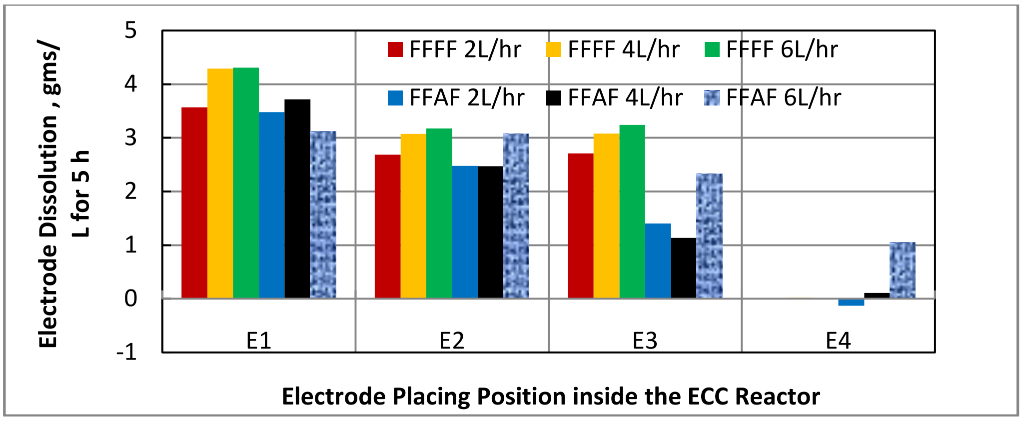


Fig 5. Effect of flowrate on electrode dissolution w.r.t placing position for both Fe_1-Fe_2-Fe_3-Fe_4 (FFFF) and Fe_1-Fe_2-Al_3-Fe_4 (FFAF) electrode arrangement

For Fe_1-Fe_2-Al_3-Fe_4 at a flowrate of 2, 4 and 6Lph, the maximum ED of 3.4769, 3.7192 and 3.1191 g/2L took place at feeder anode electrode placed at 1st position(E1). In the case of Fe_1-Fe_2-Fe_3-Fe_4 for 2, 4 and 6 Lph, the maximum electrode dissolutions were 3.5688, 4.2904 and 4.3083 g/2L for the electrode in the 1st position in the ECR. electrode deposition was observed on cathode in the Fe_1-Fe_2-Al_3-Fe_4 electrode arrangement operated at 2 Lph. Thus, with the increase in the flowrate, the electrode dissolution decreased with respect to their placing position from the feeder anode.

4.2 Effect of electrode type and position in the ECR for electrode dissolution, sludge quantity and operating cost

ECC treatment operated in a continuous mode was carried out for different flow rate of 2, 4 and 6 Lph for Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 and analyzed to workout the economic feasibility of ECC treatment. The economic parameters such as electrode dissolution, sludge generation, energy consumption and operating cost for treating fluoride and arsenic groundwater for 5.45 h reaction time is shown in Fig. 6.

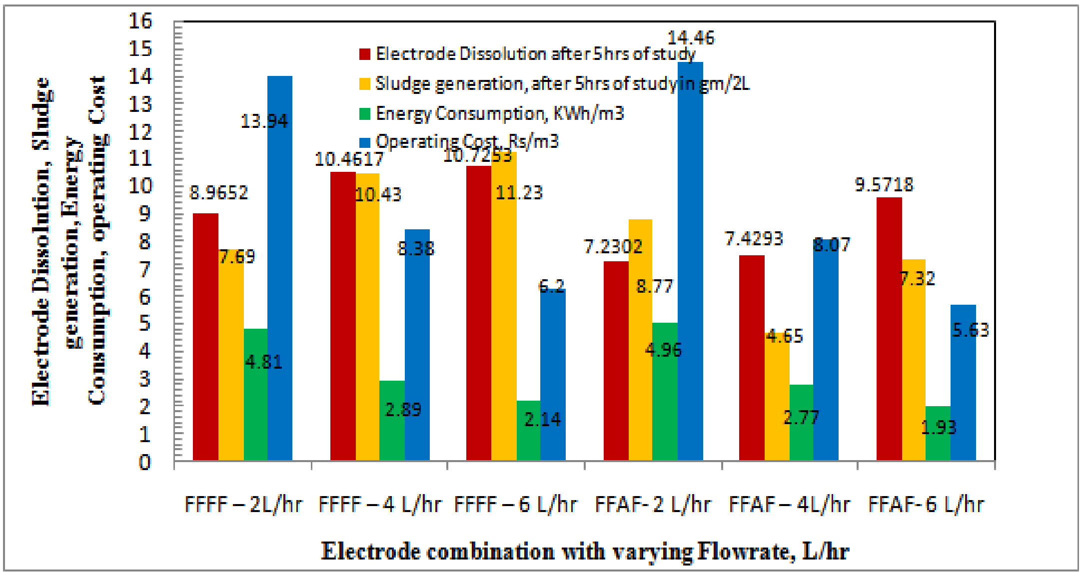


Fig.6 Effect of flowrate on (i) electrode dissolution (ii) sludge production (iii) energy consumption and (iv) operating cost as a function of Electrolysis Time

From the plot, for Fe_1-Fe_2-Fe_3-Fe_4, for increase in flowrate from 2,4, 6 Lph ED was increased from 8.9652, 10.4617 and 10.7253 g/2L with a corresponding increase in sludge production of 7.69, 10.43 and 11.23 g/2L, the energy consumption was 4.81, 2.89 and 2.14 KWh/m^3. The operating cost was seen to decrease with increase in flowrate at the rate of 13.94, 8.38 and 6.20 Rs/m^3. Using Fe_1-Fe_2-Al_3-Fe_4 electrode arrangement electrode dissolution increased with increase in flowrate i.e 7.2302, 7.4293 and 9.5717 g/2L with corresponding sludge generation of 8.77, 4.65 and 7.32 g/2L.The energy consumption for 2, 4 and 6 Lph were 4.96, 2.77 and 1.93 KWh/m^3 with operating cost of 14.46, 8.07 and 5.63 Rs/m^3. Thus, Fe_1-Fe_2-Al_3-Fe_4 electrode arrangement with 2Lph prove to be an effective flowrate for achieving effective and efficient arsenic and fluoride free drinking water.

V. Conclusion

Results of the present research study showed that continuous ECC studies for electrode arrangement Fe_1-Fe_2-Fe_3-Fe_4 and Fe_1-Fe_2-Al_3-Fe_4 with GAC filter column of 22cm depth decreased the concentration of arsenite and fluoride along with other drinking water quality parameters within the WHO and BIS drinking water quality. with the operating condition: V:16 Volts; $As(III)_0$: 2.54 mg/L; F^- : 12 mg/L; N: 4E ; Electrode arrangement: Fe_1-Fe_2-Al_3-Fe_4; interelectrode space: 5mm; Carbon Bed Depths: 22cm & 44cm; Flowrates (a) 2 L/h, 4L/h and 6L/h; ET: 350 min as a function of Reaction time on simultaneous removal of Fluoride and Arsenite in ECC reactor and at various carbon depths. The electrode arrangement Fe_1-Fe_2-Al_3-Fe_4 with 2Lph the maximum simultaneous removal of arsenite and fluoride occurred. The CECC studies revealed the fact that lower the flowrate more is the contact time available for adsorption of arsenic and fluoride ions. The other water quality parameters were well within the BIS drinking water standards. Using Fe_1-Fe_2-Al_3-Fe_4 electrode arrangement electrode dissolution increased with increase in flowrate i.e 7.2302, 7.4293 and 9.5717 g/2L with corresponding sludge generation of 8.77, 4.65 and 7.32 g/2L.The energy consumption for 2, 4 and 6 Lph were 4.96, 2.77 and 1.93 KWh/m^3 with operating cost of 14.46 , 8.07 and 5.63 Rs/m^3. The study showed that CECC treatment is a promising purification technology for the treatment of groundwater containing high concentrations of arsenite and fluoride. The outcome of this study will be useful for further application in designing economically and environmentally feasible CECC reactors for the treatment of raw groundwater polluted with As(III) and F^- and as for small settlements.

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