

Treatment of Arsenic Contaminated Water by Electrocoagulation Using Punched Iron Electrode

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Abstract - In the current examination, adsorption of arsenic in electrochemical reactor was analyzed for expulsion of both As (III) and As (V). In a lab increase electrochemical set two iron terminals were taken in a Glass measuring utencil and direct current was gone through the punched anodes, to produce Hydrous Ferric Oxide (HFO) and to get more effectiveness. The impact of functional boundaries like momentum thickness, charge thickness, and handling time on arsenic expulsion and leftover iron in treated water has been concentrated in the pH range 6-8. Trials were completed with introductory arsenic convergence of 2 mg/L with differing current thickness. Results show that watery grouping of arsenic under 50 µg/L could be accomplished, which is the drinking water standard in India and Bangladesh. It is inferred that the use of electrolytic oxidation of arsenic sullied water is more beneficial than the ordinary treatment as no synthetic substances are added. The strategy appears to hold guarantee for field applications.

Key Words: Electrocoagulation, Adsorption, Arsenite, Arsenate, Hydrous ferric oxide.

1.INTRODUCTION

In Bangladesh and India, drinking water drawn from underground sources has been answerable for far and wide arsenic harming influencing almost 100 million individuals Sarkar et al. [33]. Precipitation in this district is very critical and regularly surpasses 1500 mm/year. Unexpectedly, notwithstanding, without arsenic surface water is basically unusable because of helpless sterilization rehearses in the area and ensuing tainting with the potential for an episode of water borne infections. In numerous far off towns, arsenic debased groundwater is the lone reasonable wellspring of drinking water and financially savvy arsenic expulsion innovation is a minimum essential to give safe drinking water. Other than the presence of an inadmissible degree of arsenic, the groundwater is generally very fit for drinking Sarkar et al. [33]. Arsenic defilement of the ground water happens by both normal cycles-, for example, enduring of arsenic containing minerals and anthropogenic exercises - like uncontrolled modern release from mining and metallurgical enterprises, and use of organo-arsenical

pesticides Krishna et al. [21]. Inorganic arsenic is overwhelmingly present in regular waters. Arsenate [As (V)] and arsenite [As (III)] are essential types of arsenic in soils and normal waters (Ferguson and Gavis [12]. As (III) is more versatile in groundwater and 25 to multiple times more harmful than As (V).

High grouping of arsenic in water has caused indications of persistent arsenic harming in nearby populaces of numerous nations like India, Bangladesh, Taiwan, Mongolia, China, Japan, Poland, Hungary, Belgium, Chile, Argentina and North Mexico. Indication of higher portions of inorganic arsenic compounds in the human body prompts the infection called arsenocosis. Arsenic is a cancer-causing agent and its ingestion may maliciously influence the gastrointestinal lot, cardiovascular framework, focal sensory system and infections like skin sores, hyperkeratosis, hyperpigmentation (Farrell et al. [11]; Saha, et al. [32]. Because of its harmful consequences for human wellbeing, as of late the USEPA has brought down the greatest pollutant level for arsenic in drinking water from 50 to 10 µg l-1.

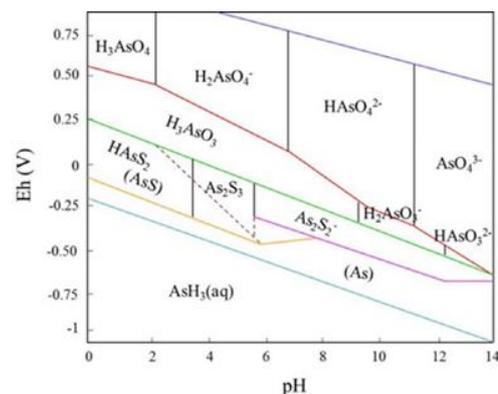


Fig-1 : Eh-pH diagram for aqueous As species

In nature arsenic exists in the types of arsenite (As(III)) and arsenate (As(V)) in watery structure and in wastewaters. Under oxygen consuming conditions, As(V) are regularly found and As(III) are common in anaerobic climate. The ionic type of arsenic species to a great extent depends on pH and redox capability of the arrangement. As displayed in Fig. 1, under diminishing conditions, the prevailing types of As(III) are impartially charged H₃AsO₃ at pH 3-9, and

adversely charged H_2AsO_3 – at pH 9–11. Under oxidizing conditions, the ionic type of As(V) species is predominantly contrarily charged $H_2AsO_4^-$ at pH 3–7 and $HAsO_4^{2-}$ at pH 7–11 Smedley and Kinniburgh [34]. Under the states of incredibly high diminished S fixation, disintegrated arsenic-sulfide species are clear in the arrangement. While As_2S_3 , and other sulfide minerals containing arsenic show up in acidic and lessening conditions Bose and Sharma, [4].

Numerous analysts have invested their amounts of energy to mitigate the issue of arsenic in water body. Various treatment choices are accessible with exhibited productivity for arsenic evacuation essentially to the level of the current MCL. Such treatment advancements incorporate coagulation Hering et al. [14], adsorption on alumina Gupta and Chen [13] anion trade Clifford [8] and turn around assimilation (RO).

Some new treatment innovations dependent on oxidation and adsorption are green sand filtration Christen [7], iron oxide covered sand Joshi and Chaudhuri [20], manganese dioxide covered sand Bajpai and Chaudhuri [3], ferruginous manganese metal Chakravarty et al. [5], ferrihydrite Jain et al. [17], earth minerals Manning and Goldberg [25] and zero-valent iron Farrell et al. [11]; Su and Puls [35], arsenic expulsion by electrocoagulation Nemade [28]. From the above conversation, unmistakably As (III) expulsion is supported by oxidation to As (V) followed by adsorption on to adsorbent. It is important to examine the treatment moves toward that would reliably furnish drinking water with arsenic under 10 $\mu g\ l^{-1}$ levels.

Electrocoagulation is an arising water treatment innovation that has been applied effectively to treat different wastewaters. It has been applied for treatment of consumable water Vik et al. [36]; Holt et al. [15], refinery spent wash Wagh et al. [37], metropolitan wastewater (Pouet and Grasmick. [30], hefty metal loaded wastewater Mills [27], eatery wastewater Chen et al. [6], arsenite Nemade and Chaudhari [29] and hued water Jiang et al. [18]. The target of the current investigation was to eliminate As (III) and As (V) by electrocoagulation utilizing iron anode which is economically accessible and nontoxic to individual.

2. THEORETICAL CONSIDERATION

Electrocoagulation offers probability of anodic oxidation and in-situ age of adsorbents (like hydrous ferric oxides (HFO), hydroxides of aluminum). As indicated by Kumar et al. [22]. As (III) may be oxidized to As (V) during electrocoagulation and gets adsorbed on to the metal hydroxides created. In this manner, it is normal that electrocoagulation would be a superior decision for arsenic expulsion from water. Past specialists have generally thought to be current thickness as a significant plan variable for EC measure. Though, according to Faraday's law disintegration of anode is identified with the all-out charge passed. In this manner the measure of adsorbent delivered in the electrochemical reactor would be relative to the charge thickness (all out charge went through

the arrangement) and may be fill in as plan boundary for EC measure.

Different conditions for the age and change of EC items created in Fe(0) EC measure are summed up in Fig. 2. In the present of disintegrated oxygen (DO), EC items at first structure as lepidocrocite (γ -FeOOH) inside the space of seconds and minutes, and the change from lepidocrocite to goethite (α -FeOOH) is seen with maturing time. At the point when DO is missing or exceptionally low, blended valent EC items, including magnetite and green rust (GR), create in Fe(0) EC measure. The creation of magnetite as an essential item is distinguished without DO and intermediates like CO_3^{2-} , SO_4^{2-} , and PO_4^{3-} . Within the sight of intermediates, GR produces as a forerunner for lepidocrocite development in oxygen consuming climate and for magnetite arrangement in anaerobic climate. The change of green rust (GR) with a more modest crystallite size into magnetite is increasingly slow contingent upon certain boundaries including electrolyte organization, pH, just as maturing conditions, which presumably brings about a deficiency of surface region. Extra examinations are needed to investigate arsenic evacuation associated with the change of GR into magnetite, which is fundamental to enhance arsenic expulsion.

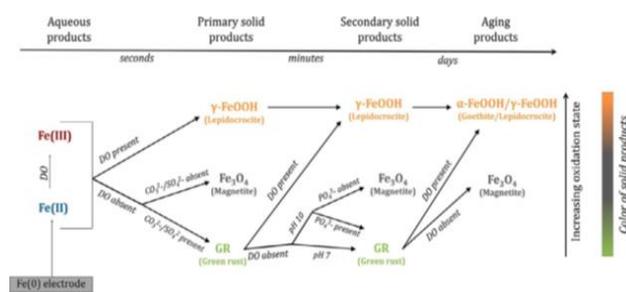


Fig-2 : Schematic diagram of the formation pathways of mixed valent Fe hydr(oxide) phases generated by Fe(0) electrocoagulation Dixon and weed [9].

3. MATERIALS AND METHODS

3.1 Reagent Preparation

Cluster tests were performed at surrounding temperatures going from 26–280 C. The synthetic substances were logical reagent grade and were utilized with no further refinement. Stock arrangements of arsenite were ready by dissolving suitable amount of arsenic trioxide, As_2O_3 , (S.D. Fine Chem Ltd., India) in refined water containing 1% (w/w) NaOH and the arrangement was then weakening up to 1 liter with refined water before use. The arsenate stock arrangement was ready from the sodium arsenate, $Na_2HAsO_4 \cdot 7H_2O$ (Loba Chemie, India). The functioning arrangements containing arsenic were ready by dissolving proper measure of arsenic from stock arrangements in faucet water. Faucet water was tried for the pH, alkalinity, and the presence of arsenic, iron and phosphate. It was tracked down that the pH of the water differed from 7.2 to 7.5, bicarbonate alkalinity was roughly

45-50 mg l⁻¹ as CaCO₃, the disintegrated iron, phosphate and arsenic focus were not discernible in faucet water.

3.2 Experimental Plan

Electrocoagulation tests were led with two iron (punched) cathodes set 0.5 cm separated in a 1.5 l measuring utensil and 1 l of arsenic containing water was added. The all out lowered surface space of every cathode was 100 cm². Prior to each test, the cathodes were scraped with sand paper to eliminate scale and afterward cleaned with progressive washes of water and 1N H₂SO₄.

An immediate flow by balanced out power supply (0-15 V, 2A) was applied to the terminal cathodes where electrical flow was constrained by a variable transformer. Since the majority of the arsenic polluted ground waters have the pH in the scope of 6 to 8, the tests were led in this pH range as it were. The pH of the arrangement was changed by adding either weaken HCl or NaOH. The outline of test conditions utilized is introduced in Table 1.

Table-1: Experimental conditions employed in Batch mode electrocoagulation

Experi ment Run No.	Arsenic type	As con c. (m g/l)	Curr ent (mA)	Current Density (mA cm-2)	p H	Reactor Volume (ml)
1	As(III)	2	30	0.30	7	1000
2	As(III)	2	40	0.40	8	1000
3	As(III)	2	50	0.50	8	1000
4	As(V)	2	40	0.40	8	1000
5	As(III)	2	30	0.30	6	1000
6	As(III)	2	40	0.40	6	1000
7	As(III)	2	40	0.40	7	1000

3.3 Method of analysis

The leftover arsenic in water test was resolved utilizing molybdenum blue complex strategy Johnson and Pilson [19]. The strategy was utilized to appraise As (III) and As (V) fixations in treated water tests to evaluate the effectiveness of the oxidation step and the ensuing evacuation of arsenic. Spectrophotometric estimations were made at a frequency of 865 nm utilizing absorbance cells of 5 cm way length for arsenic assurance.

4 RESULTS

Proper choice of cathode material is significant in electrocoagulation measure which influences the treatment proficiency. The terminal material for drinking water treatment ought to likewise be non-poisonous to human wellbeing. Subsequently iron, was picked as cathode material which was non-harmful and promptly accessible when contrasted with aluminum.

In electrocoagulation, a slight expansion in the pH was seen with time during the interaction and it was inside the administrative drinking water principles. (Vik et al. [36] noticed a similar impact during the EC cycle. The pH expansion in electrocoagulation is credited to the development of hydrogen gas at the cathode Vik et al. [36] Chen et al.[6]. Likewise a slight expansion in pH might be normal due to sorption responses of As (V) and As (III), which discharge OH-bunches from sorbents because of ligand trade Arienzo et al. [2]. There no critical impact of pH on arsenic expulsion and As (III) and As (V) evacuation up to 97 - 99 % were gotten over whole pH scope of 6 to 8 as displayed in Table 2 Kumar et al. [22].

Table-2: Summary of experimental result for electrocoagulation

pH	Arsenic type	Coagulant dose as Fe (mg l -1)				
		2.08	5.2	10.4	17.36	39.78
		Arsenic removal (%)				
6	As(III)	3	6	9	5	9
7	As(III)	9	6	9	5	9
	As(V)	5	8	1	7	9
8	As(III)	2	8	6	6	9
	As(V)	8	6	3	3	9

A few specialists revealed that current thickness can impact the treatment productivity Pouet and Grasmick. [30], while others have detailed that current thickness has no huge impact on contamination expulsion Chen et al. [6]. (Holt et al. [15] announced that expanding current thickness past a greatest worth, would not further develop the electrocoagulation cycle because of passivation of the anode.

Fig. 3 shows the fluid stage arsenic fixation as a component of time for current densities 0.3 mA cm⁻² and 0.5 mA cm⁻². It very well may be seen from the figure that up to 55-65% of the underlying focus diminished inside 10 minutes of the interaction and the remaining arsenic fixation in water was under 10 µg l⁻¹, which is the new rule worth of WHO. At first the arsenic expulsion is quick because of essence of more arsenic particles and later it diminished bit by bit as more HFO created framed buildings with arsenic over practically the whole interaction and the bends are almost stays even toward the finish of cycle (Kumar et al. [22]; Nemade and Chaudhari [29].

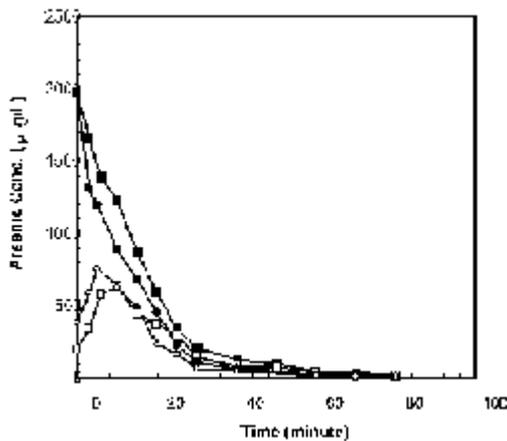


Fig-3 : Effect of current density on arsenic removal (experimental run no. 1, 3), where, symbols indicate (■) total arsenic removal [0.3 mA cm⁻²], (□) As (V) concentration [0.3 mA cm⁻²], (●) total arsenic removal [0.5 mA cm⁻²], (○) As (V) concentration [0.5 mA cm⁻²]

The outcomes acquired at various momentum densities were changed over to charge passed per liter of water and introduced in Fig. 4. The outcomes which shows that ebb and flow thickness is certifiably not a fitting boundary for evaluating arsenic expulsion from water however charge passed per liter is by all accounts a suitable boundary for surveying arsenic evacuation. It has been accounted for that arsenic expulsion increments with expanding iron doses in substance coagulation Edwards [10]; Hering et al. [14]. Essentially in Electrocoagulation, arsenic expulsion would be represented by the arrangement of hydrous ferric oxides (HFO) in arrangement (Kumar et al. [22]).

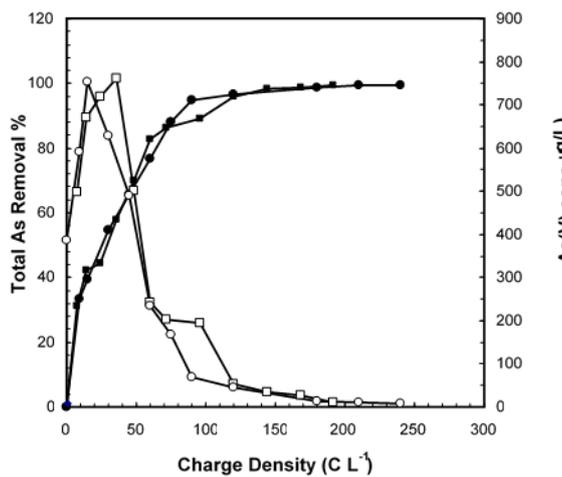


Fig-4 : Effect of charge density on arsenic removal (experimental run no. 2, 3), where, symbols indicate (●) total arsenic concentration (0.5 mA cm⁻²), (○) As (V) concentration (0.5 mA cm⁻²), (■) total arsenic concentration (0.4 mA cm⁻²), (□) As (V) concentration (0.4 mA cm⁻²).

As per Faraday's law, the charge passed to the arrangement is straightforwardly corresponding to measure of iron

disintegrated (Vik et al., 1984). This suggests that the arsenic evacuation by electrocoagulation might be administered by the arrangement of arsenic-hydrous ferric oxide edifices. It is seen from Fig. 4 that arsenic expulsion is dependent on the all-out charge went through the arrangement. Thusly charge thickness may fill in as a plan boundary for electrocoagulation measure.

It tends to be seen from the figure that arsenic evacuation was more noteworthy than 99% and the lingering arsenic fixations got were under 10 µg l⁻¹ after 190 coulombs for each liter (C l⁻¹) was passed for beginning arsenic focus 2 mg/l. As (V) fixations expanded at first toward the start of the interaction and diminished later as the all out arsenic expulsion expanded. Since toward the start of EC measure, the pace of As(III) oxidation to As(V) is more than the pace of adsorption of As(V) onto hydrous ferric oxides, as at first hydrous ferric oxides would be very less (Kumar et al., 2004; Nemade and Chaudhari [29]). Fig. 5 shows the arsenic evacuation and complete arsenic fixation at various pH (6, 7, and 8). The outcome shows very little critical impact of pH on arsenic expulsion and acquired 99 % arsenic evacuation following 80 minutes.

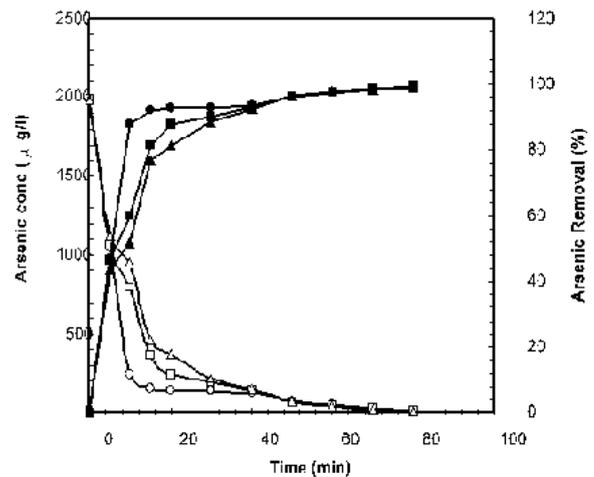


Fig-5 : Arsenic removal by electrocoagulation (experimental run no. 2, 6, 7), where, symbols indicate (●, ■, ▲) total arsenic removal for pH 6, 7, 8; (○, □, Δ) total arsenic concentration for pH 6, 7, 8.

4.1 Residual iron

In electrocoagulation, iron disintegrates from the anode and hydrogen gas is created at cathode. Faraday's law can be utilized to depict the current thickness (A/cm²) and the measure of iron which goes into the arrangement (g Fe/cm²) displayed in Table 2, (Vik et al., 1984),

$$w = \frac{itM}{ZF} \tag{1}$$

Where,

w = metal dissolving (g Fe/Fe cm⁻²); I = current thickness (A cm⁻²); t = time (sec); M = sub-atomic load of Fe (55.84); Z =

number of electrons engaged with the oxidation/decrease response ($Z=3$); $F=$ Faraday's constant, 96500. XRD of solids produced during EC with different coinciding particles are displayed in Fig. 6.

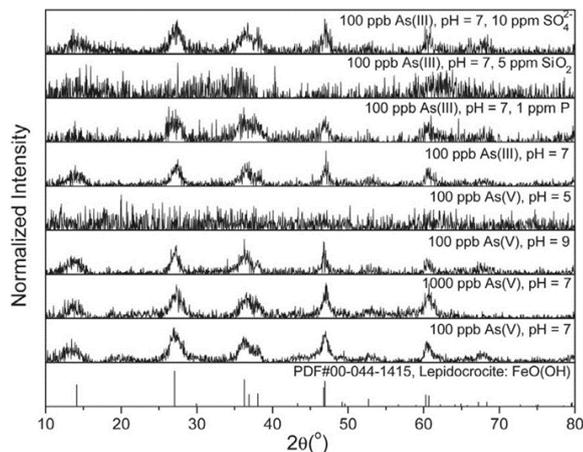


Fig- 6: X-ray diffraction patterns of solids with various coexisting ions in EC process Wan et al. [38].

5. Practical Implications

For direct viable pertinence and suggestions how much iron is required for the evacuation of As(III). Lien and Wilkin [24] revealed the arsenite expulsion limit of zero valent iron was 7.5 mg As/g Fe. Meng et al. [26]. detailed that evacuation of 90% arsenic in phosphate and silicate-rich water (1.9 mg/L P, 18 mg/L Si) required a Fe/As proportion of somewhere around 40, after the As(III) has been oxidized to As(V) with hypochlorite. Like these discoveries, Leupin and Hug [23] tracked down that 15–18 mg Fe (III) are expected to eliminate 90% of 500 $\mu\text{g/L}$ As(V) (with 3mg/L P and 20 mg/L Si). As (III) expulsion under similar conditions needed more than 80 mg/L Fe(III) Roberts et al. [31]. Conversely, option of a sum of 20 mg/L Fe(II) in eight options each 30 min Roberts et al. [31] or 15 mg/L Fe(II) added ceaselessly (this examination) was adequate to eliminate 90% of As(III) without an additional oxidant.

Bangladesh groundwater contains moderately high groupings of DOC: 3.35 mg/L (BGS and DPHE, 2001). Some extra iron may in this manner be expected to eliminate the DOC. As indicated by Aguiar et al. [1] around 2 mg Fe (II)/mg DOC are needed to co-hasten DOC with HFO without As (V). In this way, for Bangladesh, extra 6–7 mg/L Fe (II) would be required if all DOC segments contend firmly with As (V) adsorption. Also electrocoagulation measure requires 40 mg of iron expected to eliminate 99 % of 2 mg/l of As (III) and As (V) which is extremely less contrast with the cycles.

6. Conclusion

Electrocoagulation is a promising remediation device used to eliminate over 99% of arsenic from arsenic debased water and fulfilled the drinking water guideline of 10 $\mu\text{g l}^{-1}$ with iron terminal. Arsenic evacuation is fast at higher current

densities however when the aftereffects of various current thickness were changed over into charge thickness, arsenic expulsion connected well with charge thickness and in this manner charge thickness is a recommended as a plan boundary for the cycle. There is no huge impact of pH on both As (III) and As (V) evacuation in the pH range 6 to 8. As (III) was more effectively eliminated in electrocoagulation than regular strategies. Along these lines electrocoagulation can be utilized as promising innovation in country parts of West Bengal and Bangladesh as it doesn't needed any recovery, synthetics and run on battery cell (12 volt).section restates the major findings and suggests further research.

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