

Research Article

Removal of Arsenic from Groundwater using Electrochemical Coagulation Process

M. Shruthi^{a*}, S. Mahesh^a and M. Sahana^a^aDepartment of Environmental Engineering, SJCE Mysore-570 006

Abstract

Arsenic contamination is an enormous worldwide problem. Among several options available for removal of arsenic from groundwater, electro coagulation is a promising electrochemical treatment technique that does not require the addition of chemicals or regeneration. The performance of Electrochemical Coagulation (ECC) method with iron sacrificial anodes in the treatment of Arsenic rich groundwater was investigated. Influence of operating parameter i.e. voltage variation is studied in attempt to achieve optimum removal efficiency. The results obtained from the Arsenic spiked groundwater samples revealed that the most effective removal was achieved at 6V for 15 min of electrolysis duration in which As concentration was well within the prescribed drinking water standards 0.01 mg/L. pH varied within the drinking water standards 6.5 to 8.5. This method was found efficient, relatively fast and clean compared to other conventional methods, such as chemical coagulation.

Keywords: Arsenic, Groundwater, Electrocoagulation, Iron electrodes

1. Introduction

Arsenic, a toxic trace element present in natural waters (ground & surface water), has become a major unavoidable threat for the life of human beings and useful micro-organisms (H. Ghiew et al., 2009). Due to its high toxicity, World Health Organization (WHO) has lowered the maximum contaminant level (MCL) for arsenic in drinking water from 50 to 10 µg/L (WHO, 2001). Arsenic in potable water causes a major public health problem threatening the lives of over 150 million people worldwide. Primary potable water supplies are contaminated in Argentina, Bangladesh, Cambodia, China, Chile, Hungary, Mexico, Turkey, Vietnam, West Bengal (India), some areas of the United States and more contamination continues to be discovered. Bangladesh is the hardest hit, with 35–77 million of its citizens exposed to above limit of the World Health Organization (WHO) which is 10µg/L. The most commonly used technologies include co-precipitation with alum or iron, adsorption onto coagulated floc, ion exchange resin, reverse osmosis and membrane techniques. The major drawback of all these techniques is that they are unable to remove As(III) efficiently. Recently, Electro coagulation has a more prominent role in the drinking water treatment because it provides some significant advantages such as quite compact and easy operation and automation, no chemical

additives, high velocities and reduced amount of sludge (P.K. Holt et al., 2002).

In the present study, an attempt has been made to remove As from contaminated groundwater using electrocoagulation method and the process operating parameters were optimized.

2. Arsenic removal mechanism with EC

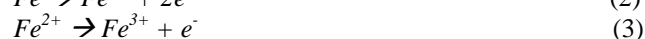
EC consists of an in situ generation of coagulants by an electrical dissolution of Fe electrodes. The generation of metallic cations takes place at the anode, whereas at the cathode, typically a H₂ production occurs. The generated gas helps the flotation of flocculated particles, and therefore the process sometimes is named as Electro flocculation. In case of application of iron electrodes, the process generates iron hydroxides, which would co-precipitate with arsenic anions. The main electrode reactions are as shown in following equations described by (H.K. Hansen et al., 2007);

Anodic reactions

(a) Single step oxidation of Fe into ferric ion

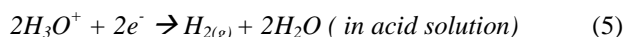
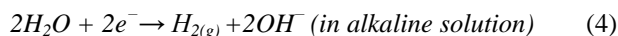


(b) A two step process where iron is firstly oxidized to ferrous ion which, depending on anode potential, then oxidizes to ferric ion

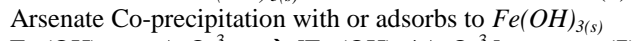
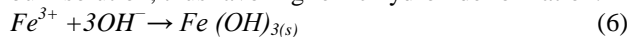


*Corresponding author **M. Shruthi** is a Research Scholar, **M. Sahana** is a Research Assistant and **Dr. S. Mahesh** is working as Professor

Cathodic reactions



Typically at the cathode the solution becomes alkaline with time. The applied current forces OH⁻ ion migration to the anode, so the pH near the anode is higher than in the bulk solution, thus favoring ferric hydroxide formation:



Thus the arsenic from the groundwater is removed.

3. Experimental setup and Procedure

Electrocoagulation was conducted in a 1 L reactor capacity. The iron electrode plates were cleaned manually by abrasion with sand paper and treated with 15% HCl for cleaning followed by washing with distilled water prior to their use. The anode and cathode were positioned vertically and parallel to each other with an fixed inert electrode gap of 1 cm. A direct current dual power supply unit (Textronix-35 D, India; 0-10A, 0-16V) was used as power source to supply and maintain current and voltage across the electrode system by means of copper wires. The reactor content was kept under complete mixed condition facilitated by means of a magnetic stirrer to avoid concentration gradients. To follow the progress of the treatment, samples were periodically withdrawn from the reactor, the filtered and analyzed for arsenic removal efficiency. All tests were conducted at room temperature and atmospheric pressure. At appropriate time intervals, DC power source was turned off and the reaction was terminated. The influence of various operating parameters is studied as a function of arsenic removal. The supernatant samples were periodically withdrawn from the reactor, then filtered and analyzed. Arsenic concentration will be analyzed using Inductively Coupled Plasma spectrophotometer (ICP). At the end of the experiment, the solution was filtered and the precipitate was dried and weighed for further analysis.

4. Results and Discussion

Ground water prior to its use in EC experiment had the following characteristics: pH 7.5-7.8, turbidity 1-1.5 NTU, total hardness 300-304 mg/L, chlorides 120-125 mg/L, total solids 8-10 mg/L and Sodium Arsenite was spiked to the groundwater to obtain the desired concentration.

4.1 Effect of Electrolysis Duration, Voltage in Arsenic Removal

The batch study was conducted with a working volume of the reactor of about 1000ml. Iron electrode of surface area 25 cm² were used as anode and cathode material. The initial set of experiments was conducted at the existing As spiked water pH. Fig 1 shows Arsenic removal curves for

different cell voltages 6V, 12V and 16V respectively for initial As(III) concentration of 0.5 mg/L for a two iron electrode connected in monopolar mode. From the plot, for an applied voltage of 6V, As (III) concentration was reduced from 0.5 mg/L to 0.01 mg/L for 20 min electrolysis. Further for 12V and 16V the removal of Arsenic showed the variation and its removal efficiency decreased, because of the side reactions that are associated with higher voltages. Arsenic removal was well within the prescribed WHO standards within 15 min of ET. The pH of the bulk solution in the ECR showed the variation within 6.5 to 8.5.

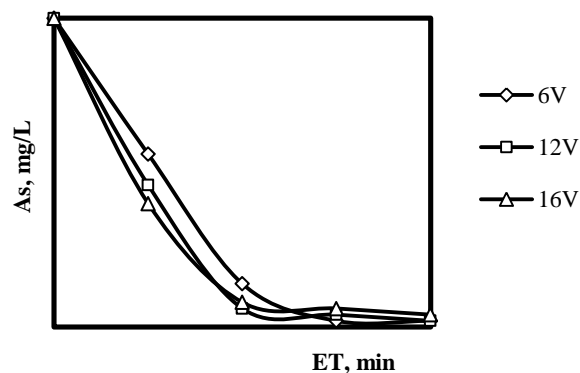


Fig 1 Effect of Voltage on Arsenic removal efficiency as a function of Electrolysis time

4.2 Effect of Initial Arsenic concentrations on Arsenic removal

EC was carried out in the concentration range of 0.05, 0.08 and 0.1 mg/L to evaluate the efficiency of arsenic removal. In order to simulate the groundwater of 0.05, 0.08 and 0.1 mg/L concentrations of arsenic ions solution were prepared by mixing proper amount of sodium arsenite. Fe electrode assembly in EC process was found to be very promising for arsenite removal as shown in Fig 2. Oxidation of sacrificial iron electrode resulted in the formation of hydroxyl polymers. All these hydroxides, polyhydroxides, etc have strong affinity for dispersed particles as well as counter ions like arsenite and arsenate to cause coagulation. For low arsenite concentration samples, the arsenic in the treated water was almost absent. In general, the removal efficiency for low arsenite concentration samples was much more as compare to the higher concentration solution. The reason for this trend is quick absorption of low concentration of arsenite on these hydroxides; generated during the electro-coagulation process. From the curve, it is observed that as the initial concentration of the arsenic increases, the removal efficiency was less and it took more time for the removal. As (III) removal to below 0.01mg/L took more time when the solutions had higher initial As (III) concentration. When the initial arsenic concentrations were higher, more iron oxides were needed to decrease the dissolved arsenic concentrations. Arsenic removal is consequently limited by the production rate of lepidocrocite. However, the final As removal efficiencies were independent of the initial As (III) concentration.

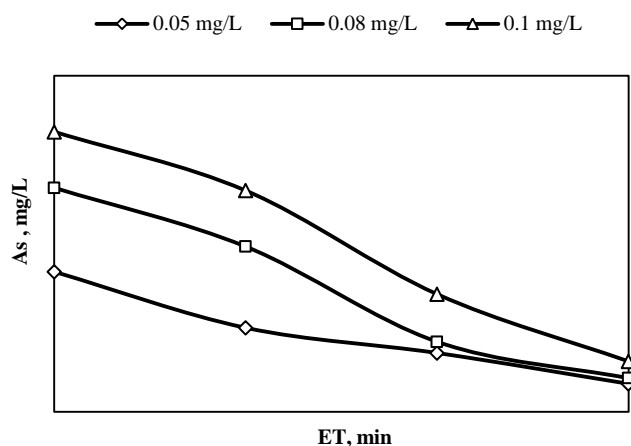


Fig 2 Effect of initial Arsenic Concentration as a function of Electrolysis time

4.3 pH variation Studies as a function of Electrolysis Time

During the batch electrochemical studies, pH of the water showed variation due to various electro-chemical reactions involved during the process. Fig 3 shows the variation in pH as a function of electrolysis time. For variation in initial concentrations such as 0.05 mg/L, 0.08 mg/L and 0.1 mg/L and the initial pH was 6.75, 6.65 and 6.8 respectively. There was not much variation in pH was observed and it was well within the drinking water standards. The final pH after the electrolysis for initial concentrations like 0.05 mg/L, 0.08 mg/L and 0.1 mg/L was 7.56, 7.65 and 7.21. Ferric and Ferrous hydroxide is produced at an optimum pH range 6.5 -8.5.

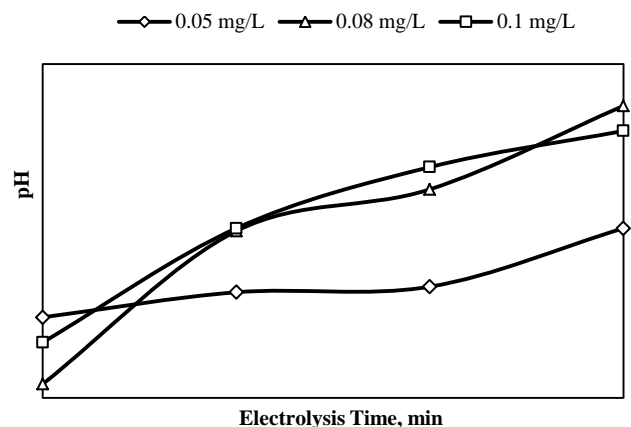


Fig 3 Variation in pH as a function of Electrolysis time

5. Conclusion

The results of this study have shown the applicability of batch ECC as a clean technology for the treatment of arsenic rich groundwater. The full potential of EC as an alternative water treatment technique to remove arsenic from well water is yet to be fully realized. EC comprises complex chemical and physical processes involving many surface and interfacial phenomena. The most effective removal capacity is achieved at 6V were As concentration was reduced from 0.5 mg/L to 0.01 mg/L. It was noticed that as arsenic concentration increased that removal efficiency decreased. pH of the water after electrolysis time was well within WHO standards. Thus iron electrodes prove to be more efficient to remove arsenic. Thus EC technique is a very promising technology for removal of toxic and heavy metals especially arsenic, where adjustment of pH is not required during EC process.

References

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