Original Article *J Res Health Sci, Vol. 8, No. 1, pp. 18-24, 2008*

Removal of Water Turbidity by the Electrocoagulation Method

Rahmani AR. PhD

Dept. of Environmental Health Engineering, Center of Health Research, Hamadan University of Medical Sciences, Iran

(Received 5 Nov 2007; accepted 22 Mar 2008)

Abstract

Background: Electrocoagulation is a technique involving the electrolytic addition of coagulating metal ions directly from sacrificial electrodes. These ions coagulate with turbidity agents in the water, in a similar manner to the addition of coagulating chemicals such as alum and ferric chloride, and allow the easier removal of the pollutants. Purpose of this study was to conduct experimental investigation of water turbidity removal using the electrocoagulation method.

Methods: Removal of turbidity from raw water in batch system was investigated by different voltage (10, 15, 20, 25, 30V), electrodes (Al, Fe and St) and electrolyzes time (0 to 40 min.), electrodes distance 2 cm and pH=7.5.

Results: The experimental results showed that the removal efficiency depends on the electrolyze time, types of electrodes and the applied current. From the experiments carried out at 20V, it was found that in 20 minutes the removal efficiency for Al, Fe and St electrodes was 93, 91 and 51 percent respectively. Based on turbidity removal efficiency, Al is prior to Fe and St as sacrificial electrode material.

Conclusion: In an era when environmental phenomena attract a great attention, electrocoagulation methods can be said to be a promising cleaning and purifying method for water treatment.

Keywords: *Water, Treatment, Turbidity, Electrocoagulation*

Introduction

The presence of particulate materials such as algae, clays, silts, organic particles and soluble substances in water often causes it to get turbid or colored. The settle ability of the particulate depends on the density of the material and the size of particles. The particles with density more than water should eventually settle due to gravitational force. Small particles, especially those with density close to water such as bacteria and colloidal particles may never settle and remain suspended in the water. Therefore, agglomeration of particles into a larger floc is a necessary step for their removal by sedimentation (1).

The conventional treatment method consists of adding metal salts (aluminum, iron etc.), destabilization of colloidal particles (which is called coagulation), followed by flocculation and sedimentation. In this way the application of chemical reagents like alum, lime, soda ash etc, which are widely used in good quantity, becomes imperative for clarification. This method of treatment has certain drawbacks like handling large quantities of chemicals, proper assessment of requirements, feeding of chemicals and production of large volume of sludge causing disposal problem and loss of water (2).

During recent decades research on electricity applied directly in water treatment has progressed well, making it an attractive method for coagulation or clarification of water, usually known as the electro-coagulation/electrochemical method (3). In this method di-

Correspondence: P.O. Box: 4171, Hamadan, Iran. E-mail: rahmani@umsha.ac.ir.

rect current is passed through aluminum/iron plates suspended in water (2-5).

This system causes sacrificial electrode ions to move into an electrolyte. Undesirable contaminants are removed either by chemical reaction and precipitation or by causing colloidal materials to coalesce. They are then removed by electrolytic flotation, or sedimentation and filtration. Disinfection is also accomplished by anodic oxidation (6). Donini at el. pointed out that the mechanisms of coagulation were similar for electro-coagulation and aluminum salts treatment (7). The difference is mainly in the way aluminum ions are delivered. Compared to water treatment with aluminum sulphate or ferrichloride, electrochemical aluminum/iron generation has several distinct advantages. Aluminum or iron is introduced without corresponding sulphate ions. Also there is no need for an alkalinity supply to give a reaction. By eliminating competing anions using a highly pure Al or Fe source, lower metal residuals are obtained and less sludge is produced (50-70 percent). The adjustment of Al or Fe ion dose in the water can be done easily by manipulating the dial for control of current (2).

The following electrode reactions for Al occur in this process (2):

Anode: $Al^0 \Leftrightarrow A1^{3+} + 3^{e-}$ [1]

Cathode: $2H_20 + 2^{e-} \Leftrightarrow 20H + H_2$ [2]

$AI^0 + 3H_2 \Leftrightarrow Al(OH)_3 + 1.5H_2$ [3]

Pzhegorlinski et al. determined the contribution of the individual reactions of equations 1 to 3. Each of these reactions was evaluated by the weight loss of the corresponding electrode and the volume and composition of the collected hydrogen (8).

The nascent oxygen produced is a very powerful oxidizer and oxidizes metals present in water. The nascent Al reacts with the water to form insoluble hydroxides and the colloid destabilization process is therefore analogous to that obtained with traditional metal salts. For completing the treatment, electrocoagulation is followed by the usual separation processes, i.e., sedimentation, flotation, filtration, etc (2).

The main objective of this research was to conduct experimental investigation of water turbidity removal by using the electrochemical method. Since iron, aluminum and Stainless steel electrodes have not been compared in detail for the treatment of turbid water, it is the purpose of this study to compare the turbidity removal by electrocoagulation using Stainless steel, aluminum and iron electrode materials. In addition, the effects of current density and treatment time on the process performance are explored.

Materials and Methods

Turbid water preparation

In this study the clay was supplied from Hamadan mines in the west of Iran during 2006. The collected samples were sieved and the fractions below 230 mesh were used for the study. The turbid sample was prepared by mixing 0.15 to 0.25-wt% of the 230 mesh clay fraction in 1000 ml water. Turbidity in samples was measured as NTU before and after electrolysis by using the turbidimetre (Hach 2100 N). All analyses were made done according to the standard methods (9).

Experimental Set-up and Measurements

In these experiments, the electrochemical cell consisted of a 500-ml beaker and two series electrodes. Aluminum, iron and stainless steel plates (15.0 x 4.0 cm) were used as electrodes. They were treated with the solution of HCl (15%Wt.) for cleaning prior to use. The beaker was filled with 250ml of sample turbid water, (pH=7.5), and the electrode plates were held suspended 2 cm apart in the water. The electrodes arrangement consisted of three cathodes interspersed with three anodes connected by brass rods to each other arranged as a parallel electrode plates.

Experiments were done similarly via the same electrolyzes time, electrodes distance and voltage intensity for all types of electrodes. To evaluate the direct current effect on turbidity removal, the samples were exposed to different voltage (10, 15, 20, 25, 30V) for 40 minutes respectively. In this study current was changed from 50 to 400 mA according to voltage. Primary turbidity measurement was done and then samples were taken periodically each 10 minutes for measurement of turbidity. In each run pH and EC were measured. Power was supplied to the electrodes with a DC Power Supply. A magnetic stirrer was used for stirring. Cell current and voltage were measured using Ammeter and Voltmeter. All experiments were conducted at ambient temperature (nominally 20°C). The experimental apparatus as shown in fig. 1 was set up in Hamadan University of medical sciences in 2006.

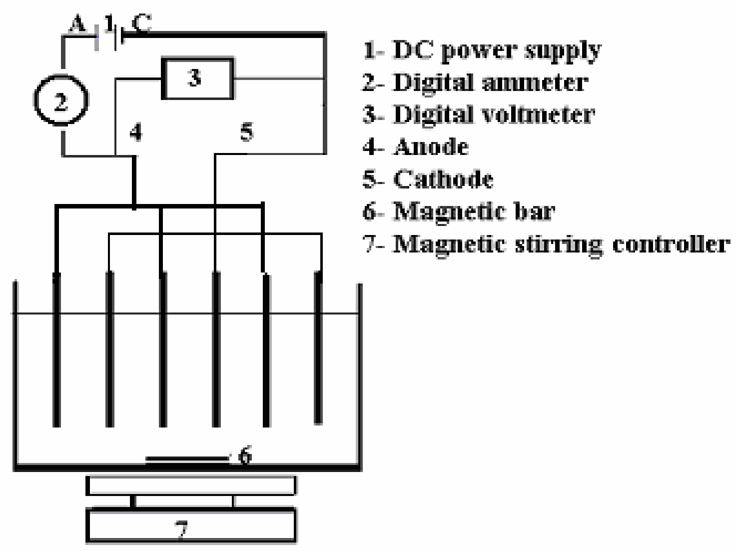

Fig. 1: Experimental apparatus

Results

The effects of direct current on water turbidity removal are shown in Fig. 2 to 4 for all combinations of electrodes. The results show that turbidity removal is increased with increasing voltage. It is found that the Al electrodes had the highest efficiency. The variation of pH and EC was low and neglect able.

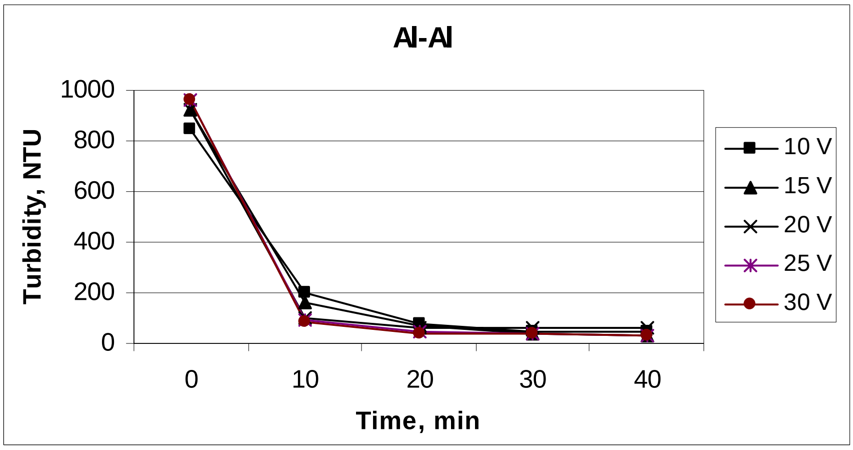

Fig. 2: Effect of current intensity on water turbidity removal by Al electrodes

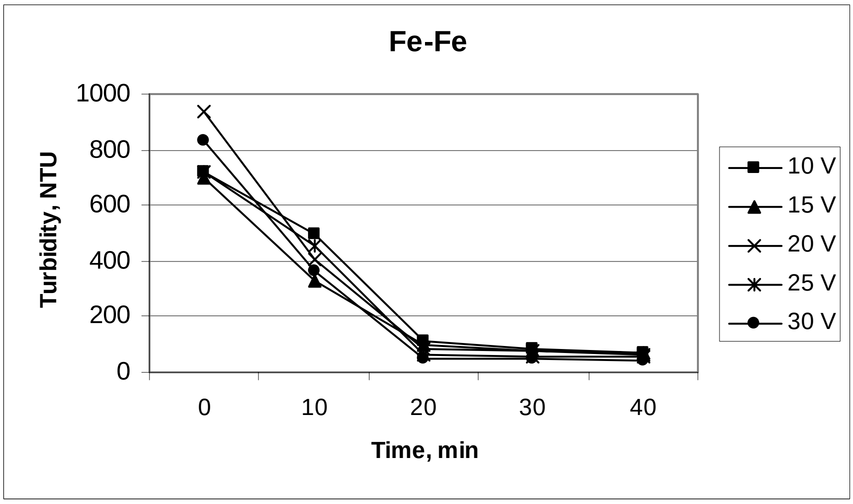

Fig. 3: Effect of current intensity on water turbidity removal by Fe electrodes

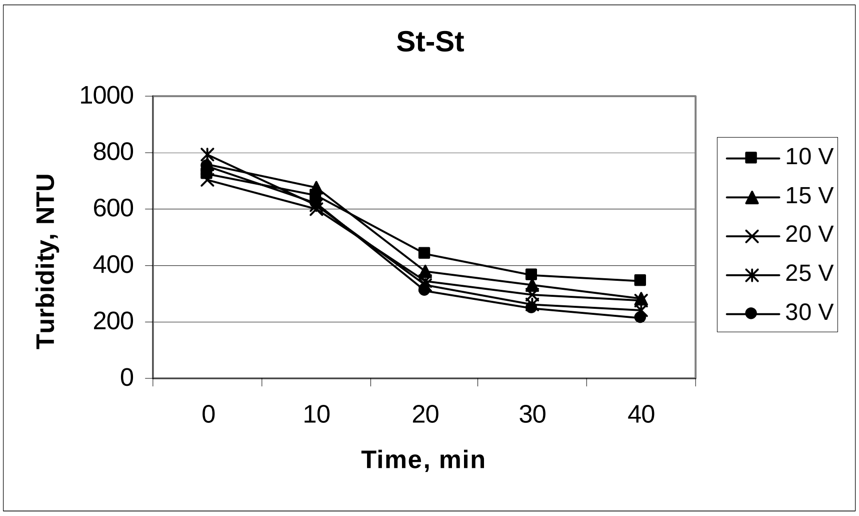

Fig. 4: Effect of current intensity on water turbidity removal by St electrodes

Discussion

Electro-coagulation has been accepted as an ideal technology to upgrade water quality for a long time and it has been successfully applied to a wide range of pollutants in even wider range of reactor designs (10). Turbidity removal occurs as the result of destabilization of colloids due to the effect of the electric field generated between the electrodes and the reactions with coagulating compounds formed in situ during anode oxidation, followed by a subsequent flotation of agglomerates of the particles (11).

Turbidity removal rate by Al electrodes appears to be higher than that by Fe and St electrodes. Turbidity removal as a function of electrodes and voltage in 2 cm distance between electrodes and 40 min contact time are compared in Fig. 5.

When Al electrodes are used, it was found that the reaction required lower current. When Fe or St electrodes are used, it is necessary to increase voltage. As seen in fig. 2 the Al electrode requires at most 10-15 min. for good removal efficiencies, while for iron electrode the time is increased to 20-25 min according to fig. 3. According to fig 4 the removal efficiency in case of St electrode is less than Al and Fe electrodes and the time required for reaching to same efficiency increased significantly. On the other hand, by comparing Fig. 2-4, it is easily seen that the current density and operating time have similar effects on process performance.

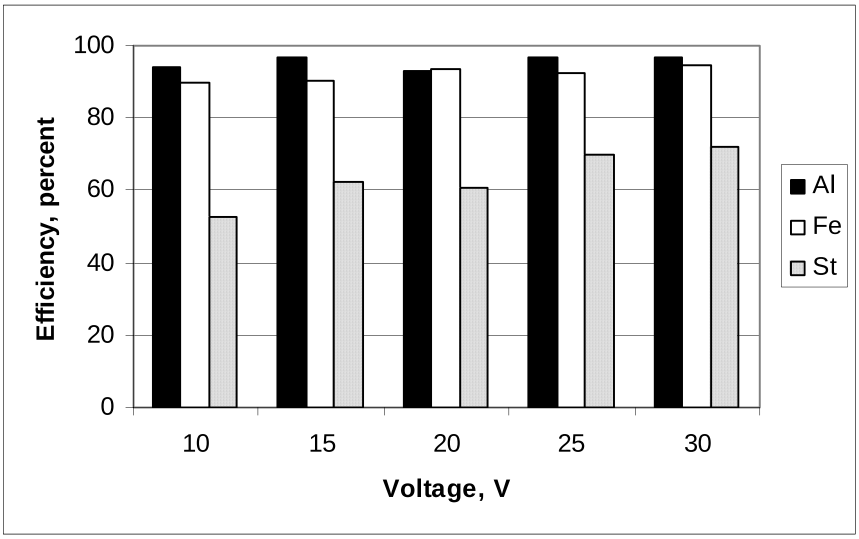

Fig. 5: Comparison of turbidity removal as a function of electrodes type (Potential: 10-30V, contact time: 40 min and electrodes distance: 2 cm)

It is thought that increasing electrolyze time or current intensity improves the efficiency of turbidity removal by faster producing hydrolyze products. During electrochemical treatment, when a potential is applied between electrodes, hydroxyl ions and Al^{3+} or Fe^{3+} are generated at the cathode and anode respectively. It is known that these products are responsible for flocculation. The possible combination of various hydrolysis products is endless and one or more of them may be responsible for the observed action of flocculation (5, 11).

It was shown that the efficiency of water turbidity removal was depended significantly on the applied current intensity and electrodes material. These enhancing effects are attributed to the increase in the driving force of the electrode reaction and the increase in current voltage. This is because potential is the major driving force for the respective phenomena of interest in electrochemical reactors (12).

The results show that turbidity removal in this study is comparable to similar experiments in the literature as discussed below:

M. Han et al. compared effectiveness of the electrocoagulation with conventional chemical coagulation through a set of batch experiments. He concluded that the electrocoagulation is more efficient than chemical coagulation for turbidity removal (4). Lai CL et al. indicated that electrocoagulation with Al/Fe pair electrode was very efficient and able to achieve 96.5% turbidity removal in less than 30 min (13). Kobya et al. studied treatment of textile wastewater by electrocoagulation using iron and aluminum electrodes. The results showed that turbidity removal for the Al electrode was as high as 98% in pH<6. So for both materials, it is clear that turbidity removal shows the same trend (3). Bayramoglu et al. show that pH is an important operating factor influencing the performance of electrochemical process. The turbidity removal in acidic medium for the Al electrode is as high as 98% and for iron in the pH range 3 and 7 is 98 and 75 percent respectively. They concluded that in acidic medium, higher removal efficiencies are obtained with Al, while in natural and weak alkaline medium iron is more efficient (14).

In conclusion, the efficiency of electrochemical methods for turbidity removal was examined in this study. By the experiments carried out at 10 V. and 135 mA current intensity, it was seen that a 10-15 minute period is sufficient for Al electrodes. By this way at the case of Fe a little bit more time or voltage was required. When the effects of voltage, electrode material and combination of them on turbidity removal were examined, as it was expected, increasing current intensity increased the efficiency. It was found that 100-300 mA is sufficient in a large scale for turbidity removal of water.

Acknowledgement

I gratefully acknowledge financial support for this project from the Environmental Health Engineering Dept., Faculty of Health, Hamadan University of Medical Sciences. I also appreciate Ms Gordan S. and, Alborzi M. for their kindly helps and efforts.

References

1. HDR Engineering. *Handbook of Public Water System*. John Wiley & Sons, 2001: pp.251-83.
2. Paul AB. *Electrolytic treatment of turbid water in package plant*. 22nd WEDC Conference, 1996:286-88.
3. Kobya M, Can OT, Bayramoglu M. Treatment of textile wastewaters by electrocoagulation using iron and aluminum electrodes. *Journal of Hazardous Materials.* B100, 2003; 163–78.
4. Han M, Song J, Kwon A. Preliminary investigation of electrocoagulation as a substitute for chemical coagulation. *J of Water Supply*, 2002; **2(5-6):**73-76.
5. Alley ER. *Water quality control handbook*. McGraw-Hill, New York, 2000: pp. 9.14- 9.20.
6. Rahmani AR, Jonidi A, Mahvi AH. Investigation of water disinfection by electrolysis. *Pakistan J of Biological Sciences*. 2005; **8(6):**910-13.
7. Donini JC. The operating cost of electrocoagulation. *The Canadian Journal of Chemical Eng.* 1994; **72:**1007-12.
8. Przhegorlinskii VI. Dissolution of aluminum electrodes in the electrocoagulation treatment of water. *Khymiya Tech Vody*. 1987; **9(2):**81-182.

9. Eaton AD, Clesceri LA, Greenberg E. Standard methods for the examination of water and wastewater. 20th ed. New York: APHA, AWWA, WEF, 1998.
10. Holt PK, Barton GW, Mitchell CA. Deciphering the science behind electrocoagulation to remove suspended clay particles from water. *J of Water Science and Technology*. 2004; **50(12):**177-84.
11. Szpyrkowicz L. Electrocoagulation of textile wastewater bearing disperse dyes. *J of Ann Chim*. 2002; **92(10):** 1025-34.
12. Philippe R, Haenni W, Pupunat L. Water treatment without chemistry. *Chimia*. 2003; **57(10):**655-78.
13. Lai CL, Lin SH. Treatment of chemical mechanical polishing wastewater by electrocoagulation: system performances and sludge settling characteristics. *J of Chemosphere*. 2004; **54(3):**235-42.
14. Bayramoglu M, Kobya M, Can OT, Sozbir M. Operating cost analysis of electrocoagulation of textile dye wastewater. *J of Separation and Purification Technology*. 2004; **37:**117-25.