

# Assessment of a Continuous Electrocoagulation on Turbidity Removal from Spent Filter Backwash Water

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## A-R-T-I-C-L-E-I-N-F-O

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## A-B-S-T-R-A-C-T

**Background & Aims of the Study:** Spent filter backwash water (SFBW) consists of 1-5% of the total treated water typically and it has a high turbidity. Because of the scarcity of water resources and in order to prevent the environmental contamination, effluent treatment of rapid sand filter backwashing is unavoidable. One of the new technologies for removal of turbidity from the effluent is ElectroCoagulation (EC) processes. This study aimed to examine the efficiency of continuous electrocoagulation in turbidity removal from spent filter backwash water.

**Materials & Methods:** This study was non-continuous experiment. A rectangular cube electrocoagulation tank in 24 cm×17 cm×18 cm dimensions from Plexiglas with the volume of 7.35 liter was made. In this tank there were 4 metal plates (electrode) (15×22×0.1cm); two electrodes as cathode and anode which were made of aluminum and iron, respectively. All of the tests were done in continuous flow. According to the study criteria (Time, Turbidity and pH), 126 sample got with the turbidity 320, 350, 400 NTU from rapid sand filter backwashing water, so they were tested in current density; 1, 1.4, 1.8, 2, 2.4, 2.8 and 3.2 ampere in 3 selected detention times (10, 20 and 30 min). Each experiment was repeated two times. In this research the space of electrode and pH is fixed at 1.5 cm and 8.2.

**Results:** In this case the highest turbidity removal for Al electrode from rapid sand filter backwashing occurred in the current density 3.2 ampere, 30 min detention time and 320 NTU turbidity. The percent of removal for Al was 95.12. The highest removal for Fe electrode from rapid sand filter backwashing occur in the current density 3.2 ampere, 30 min detention time and 320 NTU turbidity. The percent of removal for Fe was 87.40.

**Conclusion:** Regarding to the results of the tests, using electrocoagulation has an appropriate efficiency in turbidity removal.

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## Background

All water treatment facilities (conventional, softening, iron removal and direct filtration) that have granular media filters as well as low-

pressure membranes generate spent filter backwash water (SFBW) during media cleaning operations. Untreated SFBW consists of the wash water and solids carried off the top of a filter during backwash operations directly. SFBW is the largest residual stream in terms of

volume typically, though it is low in solids relative to other residual streams in general. In the treatment plant, approximately 5 percent of treated water is used for washing filters that this ratio will vary depending on the seasons (1). The volume of SFBW generated at a water treatment plant depends on a number of factors, including backwash duration, wash water rate, backwashing frequency (filter run length) and number of filters (2). The goal of the backwashing operation is to remove the deposited solids and return the media to an acceptably clean condition; so that no progressive evidence of the development of problems such as mud balls and filter cracks (discussed later) is seen in the filter bed. Rapid sand filter backwash wastewater constitutes 2-5% of the total treated water with high turbidity normally (3). Because of the lack of water resources and in order to prevent the environmental pollution in water scarce areas, it is so valuable to have a resource to discharge and returning it to the treatment process in an imperative water conservation measure. Turbidity is a nonspecific measure of the amount of particulate matter in water (clay, silt, finely divided organic and inorganic matter, microorganisms) (4). The turbidity of a sample does not convey any information about the fundamental characteristics of particles since the scattered light is the aggregate response for all particles, which is a function of the amount of particles as well as the size, refractive index, and the shape of particles (5). Fine particles, those with a density like to water especially, such as bacteria and colloidal particles may never be sediment and still stay suspended in the water. Therefore the density of the particles and their connections are necessary steps for their removal by deposition (6).

The most widely used coagulants in water treatment are sulfate or chloride salts that contain the metal ions  $Al^{3+}$  or  $Fe^{3+}$ . Limitation about the use of the alum salt is residual aluminum and suspected of being associated with Alzheimer's disease. Use of ferric chloride

in turbidity removal associated with the development of color in the water and if its value is greater than 1 mg/l can create turbidity and the taste of a drug in the water (7). The problem arises when the water that treated with ferric chloride, is exposed to air. Since 2000, in addition to the chemical coagulants, the technology of electro-chemical coagulant are used to remove most of the soluble and insoluble materials, including turbidity (8). In recent years, electrocoagulation (EC) has attracted lots of attention as an environmental friendly process; EC uses an electrical current to produce several metal ions in solution. In fact, the EC systems can be effective in removing ions, organic matters, colloidal and suspended particles, dyes, surfactants, oil and heavy metals from aqueous environments (9,10). This process is effective and affordable so that in some contaminant the removal efficiency is up to 99% (11). Advantages of electric coagulation includes adaptability with different conditions, compliance with environmental conditions, simple equipment, high-speed, no need to use certain chemicals, low sludge, low retention time, easy operation as well as the treatment of a wide range of contaminants (12). Electrocoagulation has been shown to reduce nitrate (13), arsenic (14), fluoride (15,16), dyes (17) and other organic and inorganic materials (18). The contaminants present in SFBW are maintained in solution by electrical charges. When metal ions are neutralized with ions of opposite electric charge, provided by an EC system, they become unstable and precipitate in a forming that is usually very stable. Electric current causes the concentration of charged ions on the anode, negatively; and charged ions on the cathode, positively. Metal anode is used for continuous production for the polyvalent metal cations. These cations neutralize the charge of carried particles to the anode by motion of electric current therefore facilitate the coagulation process. Removal mechanisms for the electrocoagulation process may involve

oxidation, reduction, degradation, Precipitation, coagulation, absorption and deposition (8). Because of the advantages such as high efficiency removal, simple equipments, easy operation, no need for special chemicals, low sludge, and short retention time, this method is suitable for strength and weak toxic wastewater treatment (7,11). In its simplest form, an electrocoagulation reactor may be made up from an electrolytic cell with one anode and one cathode with a direct electrical generator (10,12). The purpose of this study is reducing turbidity by electro coagulation in a continuous flow of the rapid sand filters water washing.

In the process of electrocoagulation, an electric current is introduced to contaminated water. This water has many elements such as metals and other organic materials that are being held together by their own electric charge. By adding another charge to the mix, the original charge is negated and the material breaks up. Then the materials coagulate to form a mass which can be easily removed (16). The schematic of the electrocoagulation process is shown in figure1. Therefore three main mechanisms in this process include (a) coagulant oxidation of the electrode, (b) destabilizing pollutants and (c) particles binding to clot are unstable (figure 1).

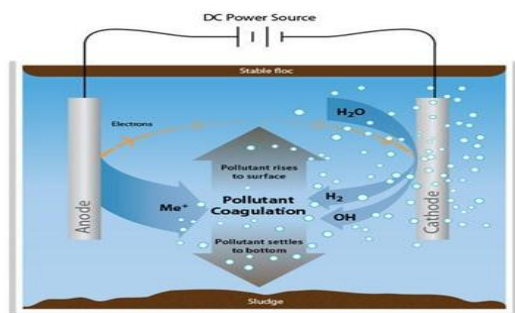


Figure 1) The schematic of the electrocoagulation process

#### Aims of the study:

The aim of this study was to determination the efficiency of a continuous electrocoagulation on turbidity removal from spent filter backwash water

## Materials & Methods

### A) Making non-continuous electrocoagulation tank reactor

In this study, an electrocoagulation reactor in a cube form to dimension (depth)  $24 \times$  (width)  $17 \times$  (length)  $18$  cm in volume 7.35 liters were made from plexiglas. In the reactor, four parallel metal plates (as an electrode) that made of aluminum or iron with a surface area of  $240 \text{ cm}^2$  and a thickness of 1 mm were installed with an electrode gap of 1.5 cm. Four-aluminum electrodes and four iron electrodes were used. All experiments were done once with aluminum electrodes and once with iron electrodes. A magnet on the bottom of the reactor was used for mixing (Magnet speed was considered 300 RPM). A settling tank was made with dimensions of (depth)  $24 \times$  (width)  $17 \times$  (length)  $53$  cm from plexiglas to the volume 21.5 liter (for settling time of 30 minutes) and the electrocoagulation reactor and the settling tank were conjoined and there are a series. A pipette is used for injecting the solution (in the vicinity of incorporation). After the desired retention time (10, 20 and 30 minutes), the solution is overflowing from electrocoagulation reactor and enters to the settling tank. The settling tank retention time was considered 30 minutes.

To supply and adjustment of an electrical current, a digital electric transformer (Matrix Ltd (MS-3005I) ) was used that has ability to transform AC power into the direct current. This amplifier was configurable (0-6 MA). Current density was set in the amount of 1.1, 1.4, 1.8, 2.4, 2.8 and 3.2 am-pere.

### B) Preparing the electrodes

4 metal plates (electrodes) were used in useful dimensions  $15$  (width) $\times$   $16$  (length) cm. these plates were made from two types of soft iron ST-12 and aluminum 3003 (because the purity is more than 99%) with a diameter of 1 mm. The electrodes were installed with an electrode gap of 1.5 cm.

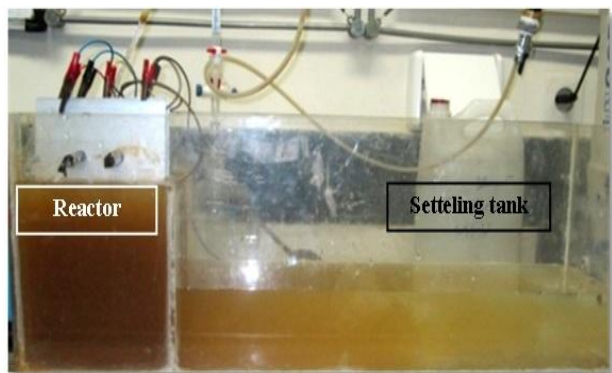


Figure 2) The Electrocoagulation reactor and settling tank

Before each test, the electrodes were worn with a soft polish until the shells are destroyed and then rinsed with sulfuric acid 1N. In this study, two electrodes as an aluminum-anode (the victim) and two electrodes as the iron-cathode were used (parallel monopole). All measurements were performed according to the techniques mentioned in the book for standard techniques of water and wastewater experiment (19).

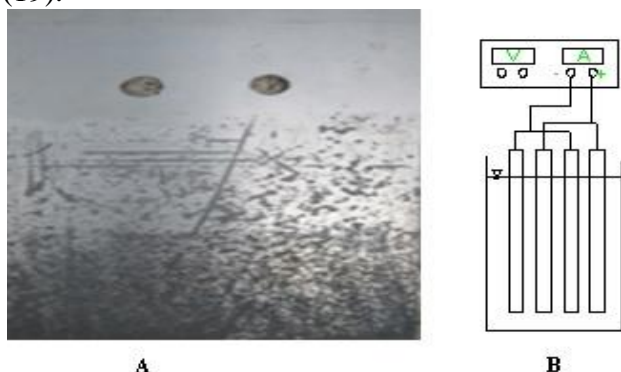


Figure 3), A) Aluminum Electrode after the Experiment B)Parallel monopolar structure

### C) Effluent sample preparation and injection into the electrocoagulation reactor

SBFW was kept in the tank for 1 hour immobilized; in case of a settling particles (one hour), the particles to be removed after dilution (if necessary) were entered into the mixing tank. To adjust the pH of the SFBW, sulfuric acid and sodium hydroxide (1N) 0.1 normal were used and to adjust the electrical conductivity, 1500 Micro Siemens  $\text{cm}^{-1}$  of sodium chloride Merck Germany was used.

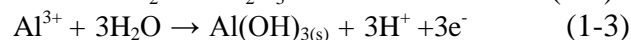
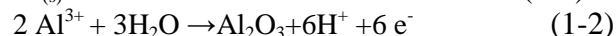
SFBW as the capacity of electro coagulation reactor and required retention time was adjusted the flow rate and after the entry into the electro coagulation reactor, a digital electric transformer (Matrix Ltd (MS-3005I) ) was used to convert the voltage 220 to the voltage 10 to 60 in which the input of the electrical transformer was urban AC power and its output was DC power. The transformer was switched on. Coagulating action with entering the SFBW to the electrodes is began and the mixer at the same time is started, causing the collision of fine particles and the formation of the bigger floc. Mixer speed of 300 RPM was selected. In fact, the mixer acts rapid and also performs the flocculation. whereas in the mix area (horizontal), rapid mixing and rotating SFBW in the reactor were done and between the electrodes (vertical flow), the flocculation is performed (for example, Accelator). After the desired retention time, the SFBW from the electrocoagulation reactor is overflowing into the settling tank. In the tank (Three taps that their position in order to provide the retention time 30 minutes before had been planted) decanting the SFBW and then purified water was out of the tap. Sampling from the tap was done at the time when the height of the water in the tank is in the middle of the tap sampling. After 126 sampling, it was read by Turbidimeter HACH 2100 (calibrated).

## Results

In the electrocoagulation process due to the pH effect on the metal hydrolysis, it requires that the preliminary experiments with different pH and selecting the proper pH were conducted.

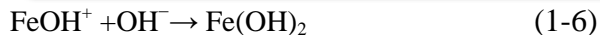
Hydrolysis of aluminum electrode as follows:

Aluminum electrode hydrolyzing is:



Iron electrode hydrolyzing is:





Due to changing in the water pH (7.4-8.6) during the test time and the importance of this subject to removal, for proper comparison with removal, optimum effluent pH between 6.8-7.4 according to the results (Figure 1) at pH 8.6, 8.4, 8.2, 8, 7.8, 7.6, 7.4 examined that amount of 8.2 was found at an optimum value.

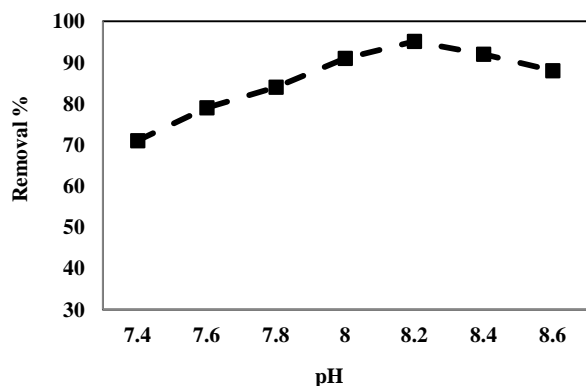


Figure 4) Effect of pH on the removal of turbidity of the effluent( turbidity 320NTU and retention time 30 min).

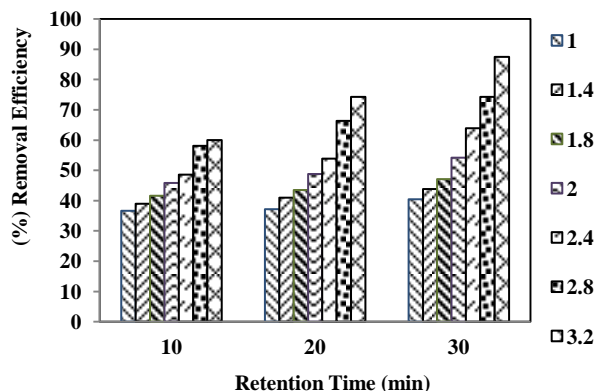


Figure 5) The effect of current density and retention time on the removal efficiency of the iron electrodes (turbidity=320 NTU pH=8.2).

Best efficiency was obtained by aluminum electrode in the current density 3.2 amps and retention time 30 min and turbidity 320.

C) The amount of power consumed and the cost of treatment:

The amount of consuming current density in terms of kWh is calculated with the following formula:

$$V \times I \times T$$

= amount of consumed current intensity

Where V is potential (v), I is current density (A), T is as Time (hour).

According to the voltage of 25 V can calculate the amount of power consumption and cost. The cost of each kilowatt per hour was determined by the ministry of energy in 2014 year about of 0.03 \$.

With regard to the optimum conditions, the calculation as follows:

Consumed current density =  $25 \times 3.2 \times 0.5 = 40$  kWh

The treatment cost of each test =  $40 \times 0.03 = 1.2$  \$ (for 30 L SFBW)

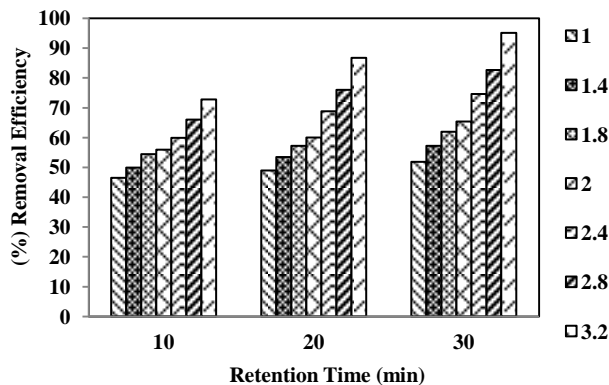


Figure 6) The effect of current density and retention time on the removal efficiency of the aluminum electrodes. (turbidity=320 NTU pH=8.2).

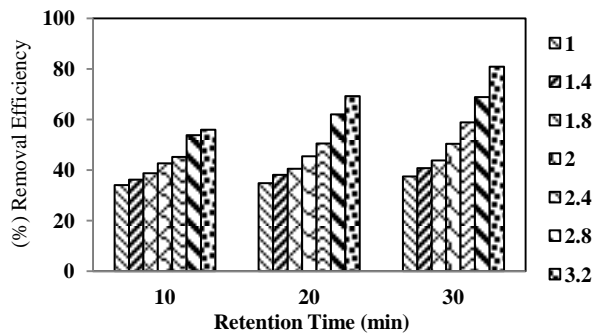


Figure 7) The effect of current density and retention time on the removal efficiency of the iron electrodes. (turbidity=350 NTU pH=8.2).

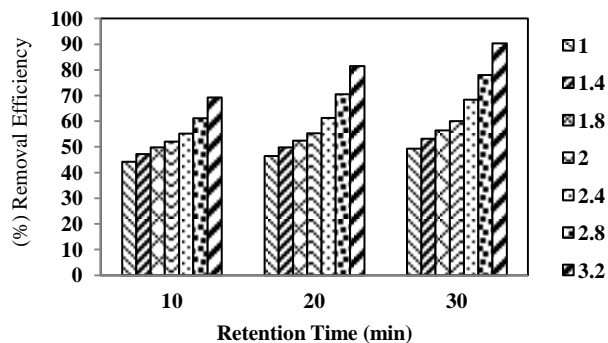


Figure 8) The effect of current density and retention time on the removal efficiency of the aluminum electrodes. (turbidity=350 NTU pH=8.2).

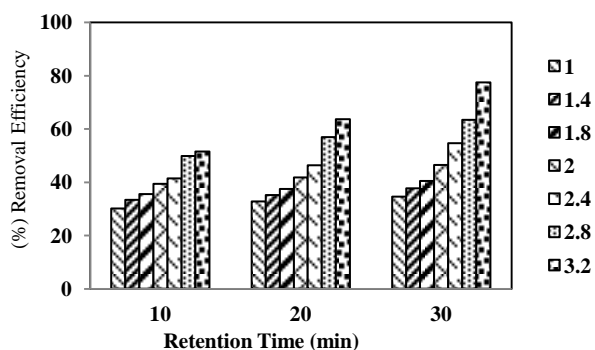


Figure 9) The effect of current density and retention time on the removal efficiency of the iron electrodes. (turbidity= 400 NTU pH=8.2).

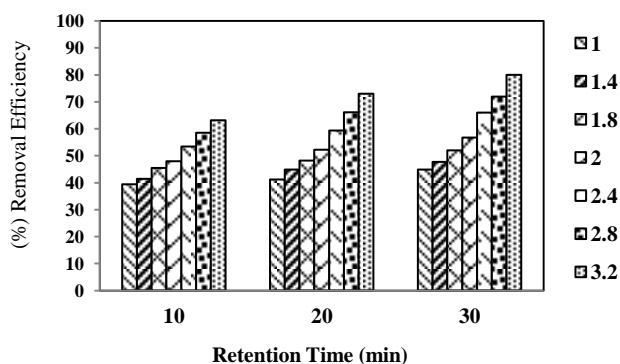


Figure 10) The effect of current density and retention time on the removal efficiency of the aluminum electrodes. (turbidity= 400 NTU pH=8.2).

Table 1) Energy consumption costs for treatment by the electrocoagulation for turbidity removal from spent filter backwash water

Time (min)	current density (Amper)	Consumed current Energy(KWh)	Cost of Consumed Current Energy (for 30 L SFBW)	Cost of treatment for one liter effluent (\$)
10	3.2	13.3	0.339	0.0113
10	2.8	11.6	0.348	0.0116
10	2.4	9.99	0.299	0.009967
10	2	8.33	0.249	0.0083
10	1.8	7.94	0.238	0.007933
10	1.4	5.83	0.174	0.0058
10	1	4.16	0.124	0.004133
20	3.2	26.6	0.798	0.0266
20	2.8	23.2	0.696	0.0232
20	2.4	19.94	0.598	0.019933
20	2	16.66	0.499	0.016633
20	1.8	14.98	0.449	0.014967
20	1.4	11.66	0.349	0.011633
20	1	8.32	0.249	0.0083
30	3.2	40	1.2	0.04
30	2.8	34.8	1.04	0.034667
30	2.4	29.97	0.899	0.029967
30	2	24.99	0.749	0.024967
30	1.8	22.47	0.674	0.022467
30	1.4	17.49	0.524	0.017467
30	1	12.48	0.347	0.011567

## Discussion

The amount of the turbidity removal from SFBW at iron electrode was between 30.1 to 87.4 percent and at aluminum electrode was 39.36 to 95.12 percent, respectively. The reason of it could be due to differences in aluminum metal structure and iron, as well as the differences in the structure and nature of the formatted flocs and the nature of the contaminants (20). As a result, by changing the anode and cathode materials, the process efficiency can vary. El nai et al in their research, used iron, aluminum and stainless steel as electrodes. The results showed that, when aluminum was used as electrodes, filtration efficiency is 5.2 times more than the other modes (21). As well as Zayed et al. in their research, used the iron and aluminum as electrodes. They showed that, both electrodes in order to reduce COD and polyphenols have the same performance, But by increasing the time the reaction rate of COD removal and polyphenols with the Al electrodes is slightly higher than the Fe electrodes (22).

In electrocoagulation process the current density is an important factor in the efficiency of the process; As in the research was revealed that the turbidity removal efficiency increases with increasing the current density. For this reason, by increasing the current density, the amount of hydroxyl metal will rise and thus increasing the active sites for the adsorption of molecules happen, and this is the cause of increasing efficiency with increasing the current strength (23). El-Nas et al conducted a study, in all states of the electrode, increasing the current density increased sulfate removal efficiency of wastewater treatment (21). Izanloo et al examined the electrocoagulation process efficiency to reduce the turbidity of water. The results showed that with increasing current density, turbidity removal efficiency increases (20).

Other important parameters in chemical, physical and biological reactions are retention time or reaction time. In this study, the average removal efficiency occurred in the first 20 minutes. It can be concluded that the majority of turbidity removal occurs in the first 20 minutes. This result is thought to be related to this fact that the efficiency of the process is directly related to the concentration of hydroxide and metal ions that are produced by the electrodes and as time passes the ion concentration and hydroxide clots increase (24).

Abdul Wahab et al were analyzed the effect of the retention time to 120 minutes, the results showed that with increasing the time, the phenol removal efficiency increases (25). The research was conducted by Tir et al at the early 6 minutes, the removal efficiency was 89 percent (26). In this study, With increasing the time to 20 minutes, the turbidity removal efficiency was 99 percent.

## Conclusion

The results show that the removal of turbidity by the coagulation - aluminum electrode is so dependent on the current density, retention time and pH. However, in this study, the amount of turbidity has an inverse relationship with the percentage removed. As well as the turbidity removal by an electrocoagulation electrode-aluminum was equal to 95.12 percent in the retention time (30 min), current density (2.3 amp) and turbidity (320 NTU). The turbidity removal by an electro coagulation electrode-iron was equal to 87.4 percent in the retention time of 30 min, current density of 2.3 amp and turbidity (320 NTU). pH is one of the important and affecting parameters on chemical reactions. Depending on the purpose of treatment (flocculation production of aluminum and iron electrodes, etc.), the optimum pH is different. In this study, the optimum pH was achieved 8.2.

## Footnotes

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### Conflict of Interest:

The authors declared no conflict of interest.

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