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TURBIDITY REDUCTION FOR THE DEVELOPMENT OF PILOT SCALE ELECTROCOAGULATION DEVICES

*Evi Afiatun[1], Hary Pradiko[1] and Evan Fabian[1]

[1]Faculty of Engineering, Universitas Pasundan, Indonesia

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ABSTRACT: A preliminary study to reduce the turbidity of drinking water by electrocoagulation method has been previously investigated. Subsequent studies were then conducted with various turbidity and initial precipitation treatments. Cikapundung River and Cisangkuy River are the main drinking water sources in Bandung with very fluctuating turbidity. In the water supply system, turbidity is one of the important factors to be observed due to several reasons such as aesthetic, consideration of load to filtration, and disinfection process. This study aims to apply the electrocoagulation process to reduce turbidity as an alternative to conventional coagulation system by utilizing Poly Aluminum Chloride (PAC). Electrocoagulation is one method of water treatment by combining the process of coagulation, flotation and electrochemistry. In this work, the electrocoagulation experiments were set up by varying the current density from 10-30 volts with 5-30 minutes detention time so that the turbidity variation could be created in a range of 25 Nephelometric Turbidity Unit (NTU) up to 400 NTU. In addition, the experiments were carried out by a precipitation process prior to the electrocoagulation process. The optimum conditions of the electrocoagulation process with both initial and non-precipitated depositions occurred at initial turbidity of 400 NTU with electrocoagulation time and with a 100 RPM fast stirring for 10 minutes to have a turbidity reduction of 99.52% and 98.28 %. The optimum current density for non-precipitating conditions was 21.33 A / m^2, whereas it is with precipitating of 46.22 A / m^2. This optimum condition is useful for a pilot scale development.

Keywords: Electrocoagulation, Optimum conditions, Precipitation, Raw water, Turbidity

1. INTRODUCTION

Drinking water sources of Bandung City come from surface water that is Cikapundung River and Cisangkuy River [1] – [3]. These raw water sources are affected by upstream conditions, pollution along the stream, as well as the climate and weather that result in this surface water quality changing over time. Water quality in Cikapundung river also influenced by hydrological and land cover factors [4]. Such conditions lead to the need for raw water treatment before being utilized. Turbidity is one of the pollutant parameters that is of primary concern as it often exceeds the quality standard. According Sawyer (2003) in the system of drinking water supply turbidity is one important factor for several reasons including aesthetic factors, filterability, the number of harmful organisms that affect the disinfection process [5].

The raw water treatment process of Bandung City generally use Poly Aluminum Chloride (PAC) as a coagulant to bind turbidity. The use of PAC increasingly large due to the condition of the quality. of raw water is getting more and more decreased [6]. The large use of PAC leads to a large and dangerous sludge of processing waste. In this regard, more efficient raw water treatment alternatives are needed and produce less sludge.

Electrocoagulation is one method of water treatment by combining the process of coagulation, flotation and electrochemistry. The electrocoagulation mechanism follows the basic principle used in the electrolysis cell system, where the anode and cathode are the sites of the reduction-oxidation reaction. The electrical energy applied to the anode dissolves the aluminum into the solution which then reacts with the hydroxyl ion from the cathode to form aluminum hydroxy. Hydroxy coagulates and flocculates suspended particles resulting in a removal of solids from treated water [7]

The research that has been done on 100 NTU turbidity concentration, obtain the optimal condition of removal process under conditions with stirring, optimum detention time 10 minutes, optimum voltage 10 Volt, and optimal current density 21.33 A / m^2 [8]. In this research, the raw water treatment process by electrocoagulation method is used to set aside the variation of turbidity concentration at the optimum condition of previous research. In this study also tested the initial precipitation process before the electrocoagulation process, as an effort to eliminate suspended particles.

The aim of this research is to analyze the efficiency of the electrocoagulation process using aluminum plate electrode to decrease the concentration of turbidity parameters in Cisangkuy

River and Cikapundung River, which further become the reference in pilot scale research.

2. RESEARCH METHODS

2.1 Tools and Materials

The tool components consist of: batch scale reactor made of glass with dimensions of 12 cm x 9 cm x 12 cm with a working volume of 1 liter equipped with 100 RPM magnetic stirrer, and floculator with a speed of 60 RPM. The dimension of the submerged aluminum plate is 7.5 cm x 7.5 cm x 0.15 cm. The dc power supply used is with an output voltage of 0 - 30 volts. Artificial turbidity is made from mud samples originating from Cikapundung and Cisangkuy Rivers.

2.2 Methods

The research was conducted on each current density at each variation of turbidity with the influence of the initial deposition process and without the influence of the initial deposition process. The research flow diagram can be seen in Fig.1.

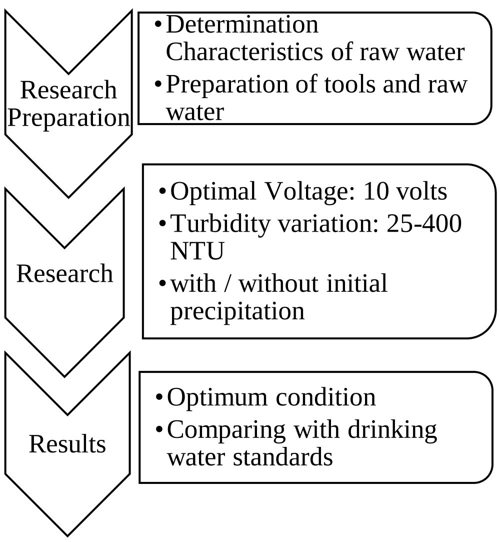

Fig. 1 Flow Chart of Research

2.2.1 Reactor Design

The sketch of electrocoagulation reactor design can be seen in Figure 2. Overall, the reactor design to be operated is as seen as Table 1.

2.2.2 Data Collection

Sampling

Samples are taken at a height of ½ - ⅔ from the bottom of the reactor and approximately 5 cm from the edge of the reactor using a pipette.

Sample Turbidity Test

Testing of sample turbidity by using Lutron turbidimeter model TU-2016.

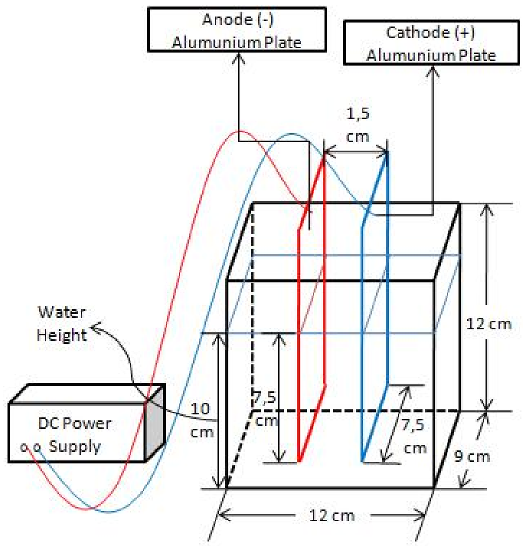

Fig 2. Electrocoagulation reactor design [8].

Table 1. Reactor operation

Electrode Type	Aluminum Plate
Distance between Electrodes	1,5 cm
Optimal Voltage	10 Volts
Optimal Detention Time	10 minutes
Number of Electrodes	One pair
The submerged plate area	7,5 cm x 7,5 cm
Rapid mixing	100 rpm, during electrocoagulation process
Slow mixing	10 minutes 60 rpm
Variety of turbidity	25, 50, 100, 200, 300, and 400 NTU
Time of precipitation after electrocoagulation process	15 minutes
The height of the plate from the bottom of the reactor	2,5 cm

Electrical Conductivity Test (DHL)

The sample was tested for conductivity by using conductivity / TDS meter of Lutron model Yk-22Ct model.

2.2.3 Data Analysis

The turbidity of samples that have been treated with electrocoagulation method then compared with initial turbidity. Electrocoagulation performance can be known from the efficiency percentage in reducing the turbidity level to meet the drinking water quality standard of Indonesian Ministry of Health Regulation No. 492 / MENKES / PER / IV / 2010. Meanwhile, the effectiveness of pollutant removal can be calculated by the formula [9].

$$R\% = (Cin - Cef)/Cin x\ 100\% \qquad (1)$$

Where :
R = Removal efficiency (%)
C in = Influent concentrations (NTU)
C ef = Effluent concentrations (NTU)

3. RESULT AND DISCUSSION

The research was conducted based on the optimum condition of preliminary research that has been done. The research was conducted using electrocoagulation process which was equipped with fast stirring using magnetic stirrer at 100 RPM for 10 minutes, followed by slow stirring using floculator with speed of 60 RPM for 10 minutes. Precipitation is done for 15 minutes.

The research was conducted on several variations of turbidity, ie 25 NTU - 400 NTU. In addition, a study was conducted by combining the electrocoagulation process with the initial precipitation process to see how much the effect of the initial precipitation on turbidity removal.

3.1 Electrocoagulation Process in Each Variation of Turbidity

The turbidity variations used in the study were 25, 50, 100, 200, 300, and 400 NTU. Each turbidity variation was treated using any variation of current density resulting from 10, 20, and 30 Volt voltages with a detention time of 10 minutes. The results were then compared with drinking water quality standards. The results were obtained as follows:

Table 2. Electrocoagulation efficiency for each variation turbidity

Initial Turbidity (NTU)	Detent-ion Time (mins)	Current Density (A/m²)	Final Turbi-dity (NTU)	Eff (%)
		21.33	2.07	91.72
25	10	46.22	1.92	92.32
		67.56	1.57	93.72
		21.33	3.38	93.24
50	10	46.22	2.56	94.88
		67.56	1.79	96.42
		21.33	1.74	98.26
100	10	46.22	0.94	99.06
		67.56	0.42	99.58
		21.33	0.37	99.82
200	10	46.22	0.00	100.00
		67.56	0.00	100.00
		21.33	0.90	99.70
300	10	46.22	0.49	99.84
		67.56	0.00	100.00
		21.33	0.66	99.84
400	10	46.22	0.21	99.95
		67.56	0.00	100.00

Turbidity value through the electrocoagulation process on each variation of turbidity and current density already meet the applicable quality standard. Graphically, the turbidity removal on each variation of turbidity and current density can be seen in Fig. 3

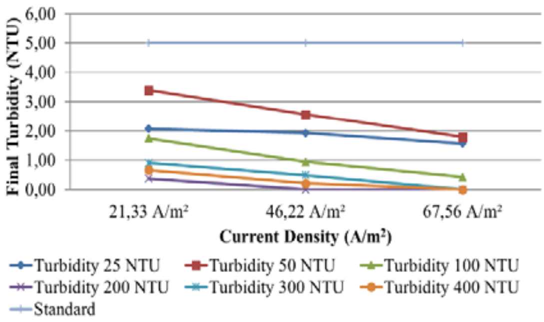

Fig.3 Turbidity removal at each variety of Current Density

Based on Fig. 3, it can be seen that the final turbidity value of the processing result is better along with the increase of current density used. The higher the initial turbidity value the higher the affluent value produced by the treatment, although there is no significant difference.

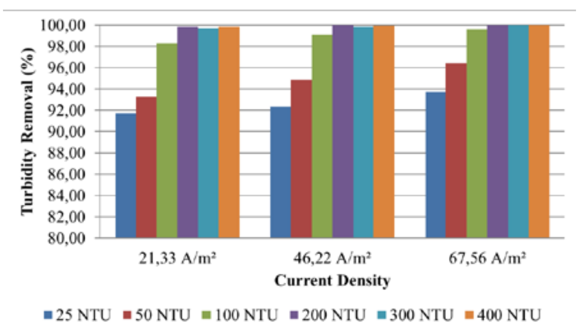

Fig 4. Processing efficiency at any variety of turbidity

Processing using the lowest current density to the highest, all of which already meet the applicable drinking water quality standards. Percentage of processing efficiency can be seen in Fig.4. From Fig. 4 it can be seen that the processing efficiency has been very high, up to exceed 91% although using the lowest current density. The higher the current density given the higher the processing efficiency.

3.2 Electrocoagulation Process with Initial Precipitation

Further experiments were carried out by combining the initial precipitation process with electrocoagulation. The turbidity variations used in this experiments were 25, 50, 100, 200, 300, and 400 NTU. Turbidity is then processed by using the current density generated by a voltage of 10 and 20 volts. After the experiments, the results obtained as follows :

Table 3. The efficiency of turbidity removal with initial precipitation and electrocoagulation

Initial Turbi-dity (NTU)	Turbi-dity after Initial Precipit-ation (NTU)	Current Density (A/m^2)	Final Turbidit y (NTU)	Eff (%)
25	19,27	21,33	5,23	72,86
50	26,27		5,62	78,60
100	34,96		5,66	83,80
200	41,06		5,55	86,49
300	55,00		7,05	87,19
400	62,67		6,90	88,99
25	19,27	46,22	3,57	81,47
50	26,27		3,29	87,48
100	34,96		2,98	91,47
200	41,06		2,79	93,20
300	55,00		2,23	95,95
400	62,67		1,93	96,92

At a current density of 21.33 A / m², the turbidity value after the initial precipitation and electrocoagulation on each turbidity variation have not been able to meet the applicable quality standards, while at the current density of 46.22 A / m² the effluent obtained is able to meet the applicable quality standards. The turbidity removal by electrocoagulation and the initial precipitation in each turbidity variation can be seen in Fig. 5.

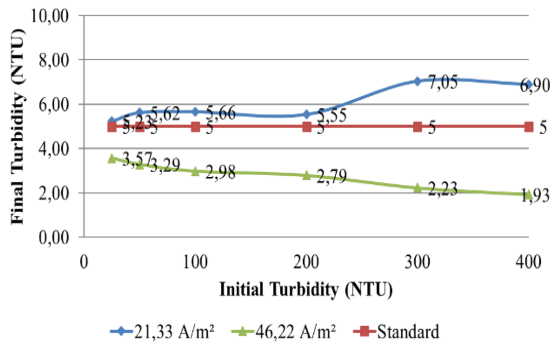

Fig. 5 Decrease of turbidity with initial precipitation and electrocoagulation

Based on Fig. 5 it can be seen that at a current density of 21.33 A / m^2 the final turbidity value increases with increasing initial turbidity of the sample. However, at a current density of 46.22 A / m² the value of the final turbidity decreases with the increasing initial turbidity. The processing efficiency can be seen in Fig. 6.

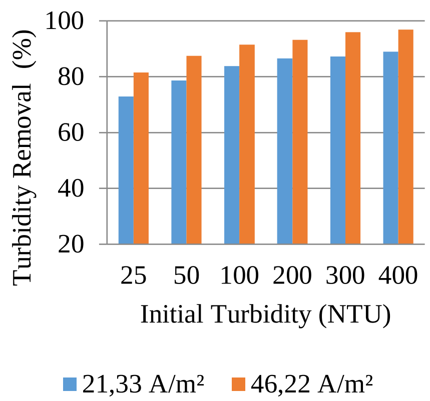

Fig 6. The efficiency of turbidity removal with initial precipitation and electrocoagulation

From Fig. 6 it can be seen that the efficiency of the turbidity removal at the initial precipitation followed by the electrocoagulation process gives better results at a current density of 46.22 A / m^2.

3.3 Comparison of Electrocoagulation With and Without Initial Precipitation

Turbidity removal with electrocoagulation and with or without initial precipitation at a current density of 21.33 A / m^2 can be seen in Fig. 7.

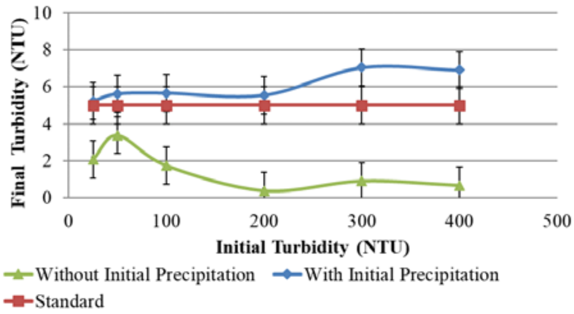

Fig. 7 The decrease of turbidity at current density 21.33 A / m²

Based on Fig. 7, it can be seen that the final turbidity value of the processing with the initial precipitation still can not meet the quality standard, while for the processing without the initial precipitation can meet the quality standard. The removal of turbidity with electrocoagulation with and without precipitation at a current density of 46.22 A / m2 can be seen in Fig. 8.

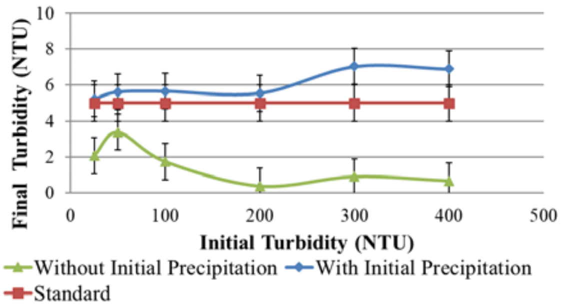

Fig. 8 Decrease of turbidity at current density 46.22 A / m²

Based on Fig. 8, it can be seen that the final turbidity value of the processing with and without the initial precipitation already meet the quality standard. The processing efficiency with and without initial precipitation at a current density 21.33 A / m² can be seen in Fig. 9.

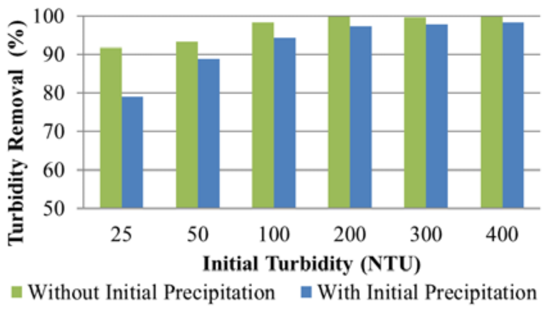

Fig. 9 Efficiency of turbidity removal at current density 21.33 A / m²

From Fig. 9 it can be seen that the efficiency of the electrocoagulation process without initial precipitation gives a higher yield than using the initial precipitation. In each variation of turbidity, there is a significant difference in efficiency when using current density 21.33 A / m^2. The processing efficiency with and without initial deposition at a current density 46.22 A / m² can be seen in Fig. 10.

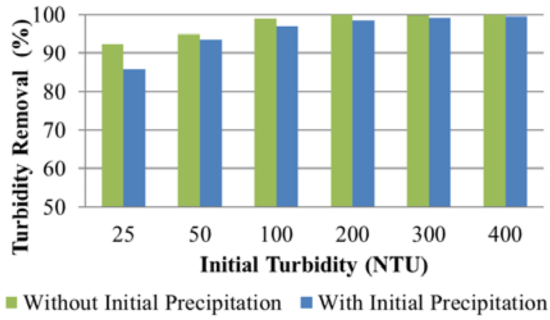

Fig. 10 Efficiency of turbidity removal at current density 46.22 A / m²

From Fig. 10 it can be seen that the efficiency of the electrocoagulation process without initial precipitation gives a higher yield than using the initial precipitation. At initial turbidity of 25 NTU there is significantly different in efficiency, whereas for other initial turbidity variation there is no significant difference. A large number of particles causes the distance between the particles closer, resulting in faster flocculation, larger floc size and more particle bonding. While at the time of initial deposition, large particles have precipitated in advance so that floc is more difficult to form

4. CONCLUSIONS

- At the current density 21.33 A/m^2 the final turbidity value of the electrocoagulation process with the initial precipitation still cannot meet the quality standard, while for the processing without the initial precipitation can meet the quality standard and gives a higher yield than using the initial precipitation.
- At the current density 46.22 A/m^2 the final turbidity value of the electrocoagulation process with and without the initial precipitation already meet the quality standard.
- The optimum conditions of the electrocoagulation process with both initial and non-precipitated depositions occurred at initial turbidity of 400 NTU with electrocoagulation time and with a 100 RPM fast stirring for 10 minutes to have a turbidity reduction of 99.52% and 98.28 %. The optimum current density for non-precipitating conditions was 21.33 A / m^2, whereas it is with precipitating of 46.22 A / m^2.
- The results of this study became the basis of subsequent research on a pilot scale

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