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Turbidity reduction by household scale electrocoagulation device

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Abstract. Pollutant parameter that often exceed the standard is turbidity, then the turbidity parameter was the main concern in this research. The electrocoagulation method is an alternative for treating water without using chemicals. This study aims to reduce the turbidity and develop previous research on electrocoagulation methods into a pilot scale with a flow rate of 0.01 L/sec. The flow rate 0.01 L/sec illustrates the water requirements for one household. In this study the electrocoagulation method was tested by the variation of electrode plates 1, 2 and 3 pairs with 3, 5, 7 and 10 Volts to treat artificial sample water with an initial turbidity of 100 NTU made from sample of raw water from Cikapundung River as one of main drinking water sources in Bandung. The optimal conditions obtained in the preliminary study were retested with turbidity variations of 25, 50, 100, 200, 300 and 400 NTU. The optimal condition of the electrocoagulation process is obtained in the variation of 2 pairs of plates with a voltage of 7 Volts and current density 23.53 A/m². The variation can treat raw water with an initial turbidity up to 400 NTU until it reaches a quality standard with a final turbidity of 3.40 NTU and the percentage of removal is 99.15%.

1. Introduction

The quality of river water as a source of raw water is influenced by environmental conditions and pollution along the river flow. This causes have declined of river water quality so it is required a treatment to meet daily needs. One of the pollutant parameters that often exceeds the clean water quality standard is turbidity [1-4].

Water treatment companies usually use PAC (Poly Aluminum Chloride) as a coagulant to bind solids dissolved in water. This process is usually used PAC in large quantities and is difficult to determine due to the fluctuation of turbidity values in the raw water [5]. Based on this problem, we need an alternative method of reducing turbidity without using chemicals such as PAC which is more practical but with the same and even better efficiency.

Electrocoagulation is the process of clumping and deposition of particles contained in water using electrical energy. The electrocoagulation process is carried out on an electrolysis vessel in which there are two direct current electric conductors known as electrodes [6]. Several studies have done with batch and continuous systems show very good results in turbidity removal. So that in this research the pilot scale electrocoagulation method was developed for household water treatment.

The purpose of this study is to develop the electrocoagulation method as an alternative to replace PAC coagulants in a pilot scale processing unit for household use.



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2. Methods

2.1. Tools and materials

Equipment components consisting of A series of processing units made of acrylic material with a continuous system consisting of an Electrocoagulation Unit, Flocculation Unit, Sedimentation Unit and Clear Tank; Aluminum plates as electrodes with submerged plate dimensions of 42.5 cm x 4.9 cm; DC power supply with 0-30 Volt output voltage; The connecting cable to connect the power supply with the electrode plate; Agitator with a stirring bar at a speed of 100 RPM; Feed tank to collect sample water with a volume of ± 200 L; Pump unit and water hose to drain water from the feed tank to the reactor.; Turbidity meter, conductivity meter and pipette volume of 10 ml. Water samples are made from tap water and Cikapundung River water as one of the drinking water sources in Bandung city.

2.2. Research steps

The implementation of this research consisted of determining the optimal variation of the electric voltage, variations of pair of plate, and current density (A/m^2) to be tested with an initial turbidity of 100 NTU. The optimum conditions will be retested with various turbidity variations (25, 50, 100, 200, 300, and 400 NTU). The optimal result based on previous research were obtained in the batch and continuous reactor occurred at 10 Volts of electrical voltage which produces a current density of $21.33 A/m^2$ [7,8]. Based on this optimal condition, a pilot scale study was carried out for flow rate 0.01 Lps (household scale) with 10 Volts voltage and also lower voltages of 3, 5, and 7 Volts. Whereas the initial turbidity was set at 100 NTU, based on the turbidity fluctuations that occurred in the Cikapundung River mostly below 100 NTU [1]. Turbidity variations in the primary research are: 25, 50, 100, 200, 300 and 400 NTU.

2.3. Reactor design

The series of pilot scale electrocoagulation processing units used during the research can be seen in Figure 1 and Figure 2.



Figure 1. The series of pilot scale electrocoagulation unit i.e.
(1-2) Electrocoagulation Unit;
(3) Flocculation Unit;
(4-5) Sedimentation Unit;
(6) Clear Tank

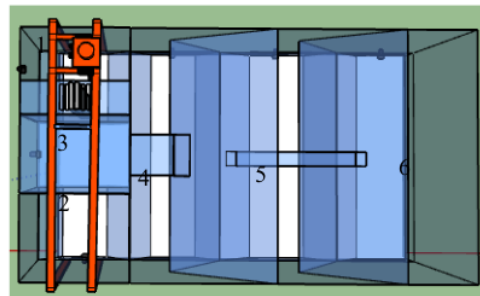


Figure 2. Sketch of the series of pilot scale electrocoagulation unit i.e.
(1-2) Electrocoagulation Unit;
(3) Flocculation Unit;
(4-5) Sedimentation Unit;
(6) Clear Tank

2.4. Data collection

2.4.1. *Sampling.* Samples were taken at each unit (except the clear tank unit) with a sampling depth of ± 10 cm from the surface of the water using a 10 ml volume pipette.

2.4.2. *Turbidity test.* The treated water samples in the pilot scale electrocoagulation unit were tested using a Lutron TU-2016 turbidity and conductivity meter. Samples were taken as much as 10 ml using a 10 ml volume pipette to measure the turbidity level and each measurement was carried out 3 times.

2.4.3. *Electrical conductivity test.* Electrical conductivity testing is carried out on the initial sample and processed sample using the Lutron model Yk-22Ct conductivity meter/TDS meter. This test is carried out by dipping the conductivity meter / TDS meter into a sample of water held in a 100 ml beaker.

2.5. Data analysis

The performance of the pilot scale electrocoagulation treatment series can be seen from the percentage of its efficiency in reducing turbidity to meet the drinking water quality standards Permenkes Number 492/MENKES/PER/IV/2010. The efficiency of reducing pollutant concentration can be calculated by the formula [9,10]:

$$R\% = \frac{C_{in} - C_{ef}}{C_{in}} \times 100\% \quad (1)$$

R = efficiency of reducing pollutant (%); C_{in} = concentration of influent turbidity (NTU); C_{ef} = concentration of effluent turbidity (NTU)

3. Results and discussion

3.1. Preliminary research

Preliminary research was carried out to obtain the optimal conditions of the electric voltage and the number of plate pairs that will be used in the primary research with varying turbidity levels.

3.1.1. *Determination of current density.* The number of electrodes used, the strength of the electric current, and the dimensions of the electrode are related to the magnitude of the current density that will be generated during the electrocoagulation process [11,12]. From the variation of the plate pairs and the voltage will be obtained the current density flowing during the processing of raw water.

3.1.2. *Variations of 1 pair plate and voltage 3, 5, 7 and 10 volts.* The results obtained in the experiment can be seen in Table 1. Based on Table 1 variation with 3 Volts voltage indicate that the final turbidity value is 10.31 NTU and is still above the quality standard (5 NTU). As for the voltage variations of 5, 7 and 10 volts, the turbidity values are below the quality standard, respectively 3.68 NTU, 2.79 NTU and 2.43 NTU. It can be concluded that for variations in 1 pair of aluminum plates with voltages 5 Volts and above can treat water with an initial turbidity of 100 NTU to reach water quality standards.

Table 1. Efficiency of turbidity reduction by variation 1 pair of aluminum plates.

Initial Turbidity (NTU)	Electrical voltage (V)	Current Strength (A)	Current Density (A/m ²)	Final Turbidity (NTU)	Efficiency of turbidity reduction (%)
100	3	0.17	8.16	10.31	89.69
	5	0.50	24.01	3.68	96.32
	7	0.76	36.49	2.79	97.21
	10	1.01	48.50	2.43	97.57

The electrocoagulation unit which is the main focus of this research produces hydrogen bubbles resulting from the reaction at the cathode which can carry pollutants to the surface of water and release Al^{3+} at the anode to form flocs which settles at the bottom of electrocoagulation unit [12]. All variations in electrical voltage produce flocs deposits at the bottom of electrocoagulation unit. Even though there is no floc formation on the 3 volts voltage above the water surface, but at the bottom the flocs are formed as a result of the reaction between Al^{3+} released by the anode.

3.1.3. *Variations of 2 pairs plates and voltage 3, 5, 7 and 10 volts.* The results obtained in these experiments can be seen in Table 2.

Table 2. Efficiency of turbidity reduction by variation 2 pairs of aluminum plates.

Turbidity in (NTU)	Electrical voltage (V)	Current Strength (A)	Current Density (A/m^2)	Turbidity out (NTU)	Efficiency of turbidity reduction (%)
100	3	0.44	7.04	5.24	94.76
	5	0.88	14.09	2.92	97.08
	7	1.47	23.53	2.05	97.95
	10	2.28	36.49	1.80	98.20

Based on table 2, variation with 3 Volts voltage still does not meet the standard with a final turbidity of 5.24 NTU. Whereas for voltage variations with 5, 7 and 10 Volts, the final turbidity numbers respectively 2.92 NTU, 2.05 NTU and 1.80 NTU where the numbers are below the standard. It can be concluded that for variations in 2 pairs of aluminum plates with voltages 5 Volts and above can treat water with an initial turbidity of 100 NTU to reach water quality standards. All electricity variations formed greater flocs at the surface water than 1 pair of aluminum plates because the stronger current electricity is also due to the use of more aluminum plates as electrodes. So that more hydrogen is produced and brings more pollutants to the surface of water. In addition the formation of flocs on the surface water carried by hydrogen, at the bottom of the electrocoagulation unit also formed floc deposits. These floc deposits are formed from the binding of Al^{3+} released by the anode so that they bind particles in the water sample.

3.1.4. *Variations of 3 pairs plates and voltage 3, 5, 7 and 10 volts.* The results obtained in these experiments can be seen in Table 3. Based on Table 3, for the variation of 3 pairs of aluminum plates with 3 Volts electricity voltage has not been able to treat water with turbidity of 100 NTU until it reaches the quality standard for turbidity parameters. The final processing result with this variation is 5.15 NTU with a 94.85% reduction efficiency. As for variations with a voltage of 5, 7 and 10 Volts, they can treat water with a turbidity of 100 NTU to reach the water quality standard.

Table 3. Efficiency of turbidity reduction by variation 3 pairs of aluminum plates

Turbidity in (NTU)	Electrical voltage (V)	Current Strength (A)	Current Density (A/m^2)	Turbidity out (NTU)	Efficiency of turbidity reduction (%)
100	3	0.59	5.67	5.15	94.85
	5	1.02	9.80	2.93	97.07
	7	1.83	17.58	1.74	98.26
	10	3.38	32.46	1.28	98.72

3.1.5. *Recapitulation of preliminary research results.* Recapitulation of research data to treat the initial turbidity of 100 NTU in each variation can be seen in Figure 3. Based on Figure 3 it can be seen that the optimal conditions occurred in variations that provide turbidity values below the quality standard and current density are close to the optimal conditions of previous studies, which is 21.33 A/m^2 . This

condition occurred in 2 variations, namely 1 pair of plates, 5 Volts of electrical voltage and 2 pairs of plates, 7 Volts of electrical voltage. Both variations are capable of removing turbidity respectively 96.32% and 97.95%. These variations will be retested in the primary research to see more efficient variations.

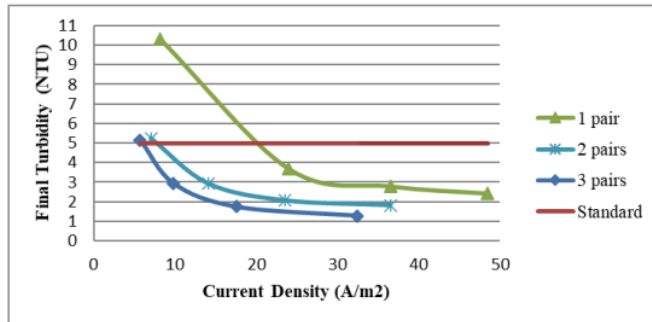


Figure 3. Recapitulation of turbidity reduction for each current density.

3.2. Primary research

The primary research was conducted to test the optimal conditions in the preliminary research with variations in the initial turbidity of 25, 50, 100, 200, 300 to 400 NTU. Based on Figure 4 it can be seen that for optimal conditions 1 pair of aluminum plates with 5 Volt electricity at an initial turbidity level of 25, 50 and 100 NTU can reduce the turbidity parameters to below the quality standard that is respectively 2.66 NTU, 2.90 NTU, and 3.34 NTU with a reduce efficiency of 89.37%, 94.19% and 96.66%. However, at the initial turbidity level of 200 NTU, this selected condition was unable to reduce turbidity into the quality standard limit (5 NTU).

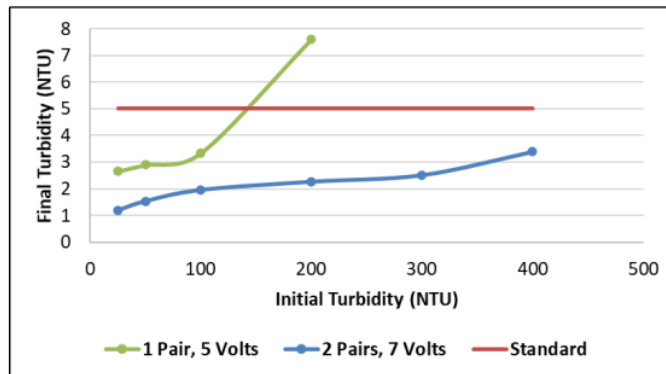


Figure 4. Test results in optimal condition.

Turbidity reduction at initial turbidity above 100 NTU is carried out using a variation of 2 pairs of aluminum plates and a voltage of 7 Volts, with the consideration that this variation gives a current density of 23.52 A/m² which is almost the same as the current density at a variation of 1 pair of aluminum plates and 5 Volts of electricity voltage, which is 24.01 A/m². Based on Figure 6, obtained processing results for initial turbidity of 25 NTU to 400 NTU with the highest removal efficiency of 99.16% for processing initial turbidity of 300 NTU and the lowest removal efficiency of 95.20% in the initial turbidity of 25 NTU.

4. Conclusion

The optimal condition for the initial turbidity 100 NTU and below was the variation 1 pair plate and 5 Volts electricity voltage with the current density 24.01 A/m^2 that can produce final turbidity 3.34 NTU and efficiency 96.86%. The optimal condition for the initial turbidity above 100 NTU, was the variation of 2 pairs of plates and 7 Volts electricity voltage with current density 23.53 A/m^2 that can treat raw water with the largest initial turbidity of 400 NTU to final turbidity reaching 3.40 NTU and efficiency of 99.15%. Optimal conditions for reducing turbidity with the pilot scale series electrocoagulation treatment are obtained at current density ranging from 23-24 A/m^2 . This figure is close to the optimal conditions in batch and continuous reactors, with a current density of 21.33 A/m^2 .

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