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Abstract. One of the main sources of drinking water commonly used as raw water is river water. This study aims to analyze the efficiency of the Water Treatment Plant using electrocoagulation techniques with modification of sedimentation unit to reduce turbidity concentration in raw water. The drinking water treatment methods without chemicals such as electrocoagulation is an alternative that is being developed as a more efficient alternative treatment. This study was conducted by testing the sample water into a Communal Scale Drinking Water Treatment Plant, with variants of aluminium pairs plates, voltages, and the addition of plate settlers to the sedimentation unit. This study was conducted at flow rates of 0.06 L/sec and 0.08 L/sec. This research results show that the optimal variation with initial turbidity of 100 NTU is 5 pairs of plates with 15 Volt electricity with a percentage of turbidity removal of 93.5% at a flowrate of 0.06 L/sec and 88.2 % at 0.08 L/sec flowrates. Under the optimal conditions, the turbidity removal is increasing in line with the increase of turbidity removal in sedimentation units. This condition shows that modification of the sedimentation process by adding plate settlers increase the turbidity removal.

1. Introduction

The method of treating drinking water without chemicals is developing a more efficient alternative treatment, including using the electrocoagulation method. The coagulation process requires coagulants to treat water, while in the electrocoagulation process, raw water is treated using reduction and oxidation (redox) reactions. In an electrocoagulation cell, the anode or electrode (+) will undergo oxidation, while the cathode or electrode (-) will experience a reduction, where the coagulant will be produced from the electrode (+), so there is no need for the addition of chemical coagulants [1]. In this case, the anode will produce Al^{3+} ions which will cause colloid destabilization resulting in floc formation.

Research on reducing the turbidity of raw water using electrocoagulation methods both batch and continuously resulted in optimal conditions for turbidity removal at a variation of 2 pairs of aluminium plates and 7 Volt electric voltage [2-4]. However, there are still some obstacles, such as not achieve G.td value (the velocity gradient during the detention time in the series of water treatment), where the value of G/sec according to the *SNI* 6774-2008 About Technical Specification for water treatment is> 750, and the processing time is too long around ± 4 hours in one processing. The research development carried out is to increase the flowrate to 0.06 L/sec and 0.08 L/sec to reach the appropriate G/sec value, shorten processing time, and ascertain if floc deposition occurs in the sedimentation unit. In this study, the addition of variations in the aluminium plate pairing, the addition of electric voltage variations and the addition of a plate settler in the sedimentation unit to compensate for the performance of the water treatment circuit due to the addition of flowrate. This research is important to meet the design criteria of the electrocoagulation method and to increase the ability of the water treatment plant to remove turbidity. This research is also important because it can be an alternative to communal water treatment.

From previous research, it is known that the turbidity value of raw water in Bandung City from March to August 2016 shows that the turbidity value ranges from 25 NTU to 600 NTU with the majority of turbidity values below 100 NTU [2, 5]. Therefore, in this study initial turbidity of 100 NTU will be used to determine the optimal conditions of the treatment plant.

This research aims to determine the effectiveness of the performance of the sedimentation unit that has been added to the plate settler in reducing turbidity in the Communal Scale Water Treatment Plant and making it an alternative to raw water treatment on a communal scale.

2. Methodology

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 with the addition of plate settler and Clear tank.
- Aluminium 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 Cikapundung River water as one of the drinking water sources in Bandung city [2-7].

2.2. Research steps

The implementation of this research consists of determining the variation of the electric voltage from 3 volts to 20 volts and the variation of the number of plate pairs from 1 pair to 5 plate pairs to obtain optimal conditions by looking at the effectiveness of turbidity reduction that occurs. The variations made are based on the results of previous research [2-4]. The addition of a settler plate to the sedimentation unit with acrylic material with a thickness of 0.3 mm with a distance between plates of 1.2 cm in both sedimentation unit 1 and sedimentation unit 2. The flowchart of this study is shown in figure 1 below:

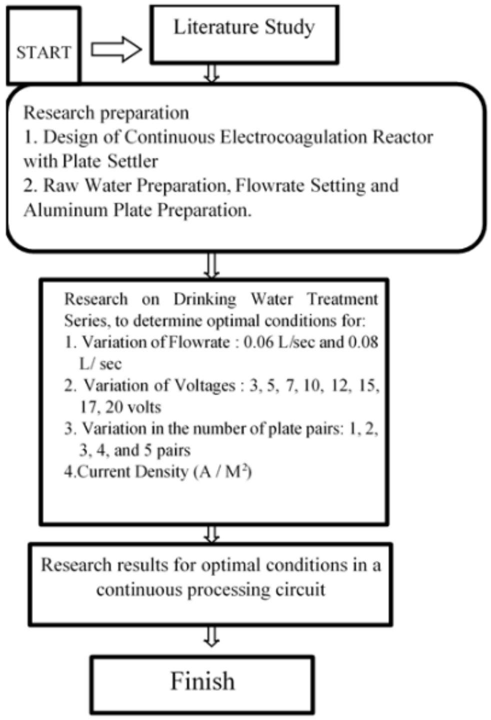

Figure 1. Research flowchart.

2.3 Reactor design

The following is a series of electrocoagulation processing units with a continuous system.

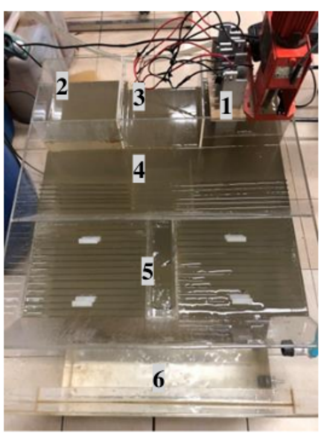

Figure 2. A series of electrocoagulation processing units.

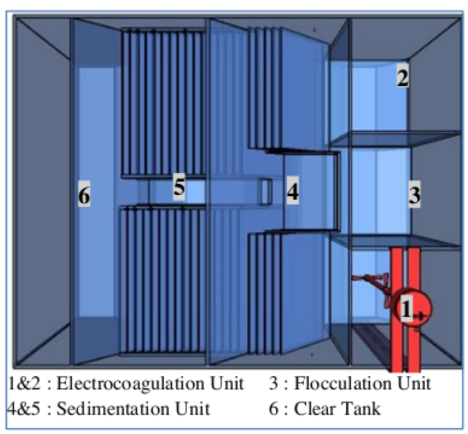

Figure 3. Plan of series of electrocoagulation processing units

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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 water's surface 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 [8,9]:

$$R\% = \frac{Cin - Cef}{Cin} \times 100\% \qquad (1)$$

Where:
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. Variations number of plate pairs with Voltage variations on flow rate 0.06 Lps

The initial turbidity value in this research was 100 NTU. The turbidity is treated using a variation of 1 to 5 pairs of aluminium plates with a variation of electric voltage of 3, 5, 7, 10, 12, 15, 17, and 20 Volts. Each variation will produce a different current density. Processing is also done with a stirring speed of 100 RPM. The following are the results obtained in the plate pair variation experiment with voltage variations of 3, 5, 7, 10, 12, 15, 17, and 20 volts at a flow rate of 0.06 Lps.

Table 1. Turbidity removal with various variations in the number of aluminium plates pair at a flow rate of 0.06 Lps.

Number of Aluminum Plate Pairs	Voltage (V)	Currents (A)	Current Density (A/m^2)	Final Turbidity (NTU)	Removal Efficiency (%)
	3	0.01	0.48	75.00	25.00
	5	0.07	3.36	66.00	34.00
	7	0.16	7.69	56.00	44.00
1	10	0.33	15.86	50.00	50.00
	12	0.19	6.78	29.32	70.68
	15	0.27	12.98	21.26	78.74
	17	0.36	17.30	19.59	80.41

Number of Aluminum Plate Pairs	Voltage (V)	Currents (A)	Current Density (A/m^2)	Final Turbidity (NTU)	Removal Efficiency (%)
	20	0,51	24,51	20	80.00
2	3	0.13	2.08	54.00	46.00
	5	0.25	4.00	48.73	51.27
	7	0.42	6.72	48.00	52.00
	10	0.79	12.64	29.43	70.57
	12	0.83	13.28	27.00	73.00
	15	1.00	16.00	21.43	78.57
	17	1.12	17.92	23.87	76.13
	20	1.36	21.76	26.00	74.00
3	3	0.26	2.50	36.64	63.36
	5	0.57	5.48	30.28	69.72
	7	0.98	9.41	32.27	67.73
	10	1.63	15.66	24.11	75.89
	12	1.42	13.64	20.67	79.33
	15	2.16	20.75	19.61	80.39
	17	2.09	20.08	16.25	83.75
	20	2.54	24.40	19.54	80.46
4	15	12.30	84.48	11.84	88.16
	17	15.00	103.02	16.83	85.00
5	15	16.00	85.47	6.50	93.50
	17	18.10	96.69	10.73	89.27

Table 2. Turbidity removal with various variations in the number of aluminium plates pair at a flow rate of 0.08 Lps.

Number of Aluminum Plate Pairs	Voltage (V)	Currents (A)	Current Density (A/m^2)	Final Turbidity (NTU)	Removal Efficiency (%)
1	3	0.06	2.88	45.28	54.72
	5	0.16	7.69	51.00	49.00
	7	0.26	12.50	49.57	50.43
	10	0.41	19.71	40.38	59.62
	12	0.34	16.35	30.29	69.71
	15	0.37	17.79	36.65	63.35
	17	0.42	20.19	27.47	72.53
	20	0,54	25.96	35.85	64.15
2	3	0.17	2.72	51.00	49.00
	5	0.38	6.08	59.00	41.00
	7	0.62	9.92	50.00	50.00

Number of Aluminum Plate Pairs	Voltage (V)	Currents (A)	Current Density (A/m²)	Final Turbidity (NTU)	Removal Efficiency (%)
	10	0.99	15.84	50.00	50.00
	12	1.16	18.56	30.71	69.29
	15	1.35	21.60	26.27	73.73
	17	1.71	27.36	21.64	78.36
	20	1.63	26.08	26.57	73.43
3	3	0.29	2.79	57.00	43.00
	5	0.57	5.48	46.92	53.08
	7	0.79	7.59	38.40	61.60
	10	1.20	11.52	34.97	65.03
	12	2.01	19.31	26.80	73.20
	15	2.25	21.61	24.05	75.95
	17	2.54	24.40	31.77	68.23
	20	2.84	27.28	26.24	73.26
4	15	13.90	95.47	20.27	79.73
	17	15.00	103.02	15.26	86.24
5	15	14.00	74.79	11.78	88.22
	17	16.10	85.47	17.22	82.78

Based on table 1 and table 2, in a variation of 3 plate pairs, with a voltage of 3 volts to 20 volts, it is found that the current density value of 20 A/m^2 - 24 A/m^2 has been reached at an electric voltage of 15 volts to 20 volts. The current density value of 20 A/m^2 - 24 A/m^2 is the value used in previous studies as a measure for the optimal allowance to reduce the turbidity of raw water to 5 NTU in accordance with the quality standard determined by *Permenkes* No. 492 of 2010 concerning Drinking Water Quality Standards [4]. However, in this study, even though the current density value has been achieved, the allowance is still not close to 5 NTU, therefore adding the plate pairs to 4 and 5 pairs by using the optimal variation of the electric voltage in the conditions of 3 plate pairs, namely 15 and 17 volts.

Based on figure 4, it can be seen the comparison of the results of the turbidity removal efficiency of each plate pair with initial turbidity of 100 NTU at a flow rate of 0.06 Lps.

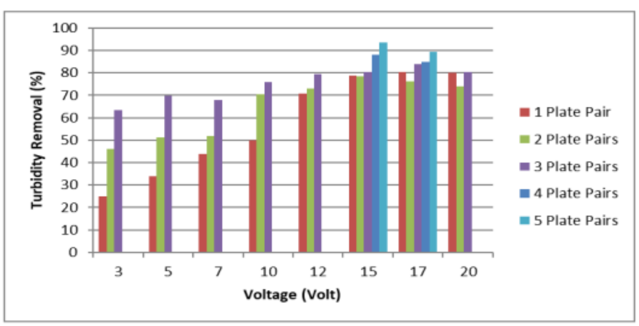

Figure 4. Turbidity removal with variations in the number of aluminium plates pair at a flow rate of 0.06 Lps.

The highest turbidity removal efficiency was at 5 pairs of plates with an electric voltage of 15 Volt, with a turbidity removal of 93.5%, with removal at the sedimentation unit of 18.52%. At the same time, the turbidity removal in plate pair variations with variations in electric voltage between 3 Volts to 20 Volts with a flow rate of 0.08Lps can be seen in figure 5.

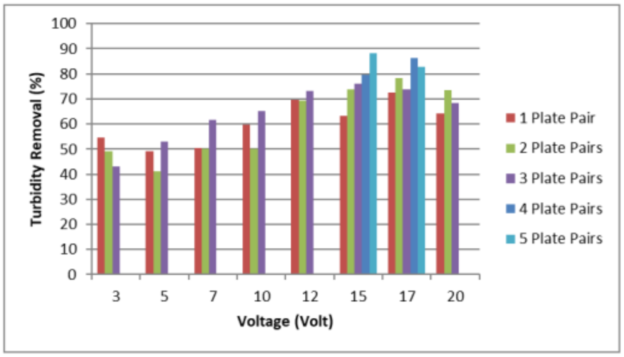

Figure 5. Turbidity removal with various variations in the number of aluminium plates pair at a flow rate of 0.08 Lps.

Based on figure 5, it can be seen the comparison of the turbidity removal efficiency of each plate pair with initial turbidity of 100 NTU at a flow rate of 0.08 Lpd. The highest turbidity removal efficiency at the flow rate of 0.08 Lpd was achieved at 5 pairs of plates with an electric voltage of 15 Volt, with a turbidity removal of 88.22%. As with the flow rate of 0.06 Lpd, the lowest turbidity value was achieved in the variation of 5 plate pairs with a voltage of 15 Volt with the final turbidity value of 6.5 NTU and 11.78 NTU, respectively. The difference in the final turbidity value at optimal conditions in the two variations of flow rates is because at a discharge of 0.08 Lpd, the detention time of water entering the electrocoagulation unit is shorter Al^{3+} from aluminium plate, and also less floc formation.

Floc deposition occurs well in the sedimentation unit based on observations of floc deposition at two flow rate variations. This indicates that the flow rate used is correct and the value of the velocity gradient (G.td) meets the limitations of the coagulation process. In the sedimentation unit which is the focus of this study, the turbidity removal in the optimal variation can be described as in the following figure:

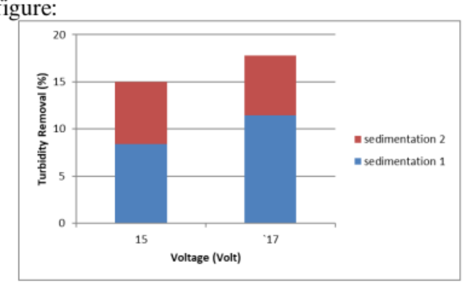

Figure 6. Turbidity removal in sedimentation units 1 and 2 at a flow rate of 0.06 Lps.

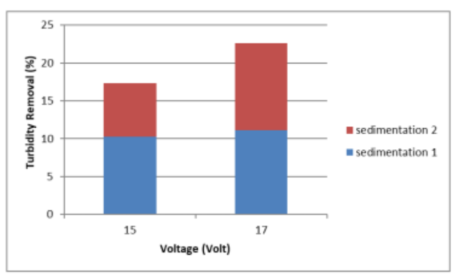

Figure 7. Turbidity removal in sedimentation units 1 and 2 at a flow rate of 0.08 Lps.

Figure 6 and figure 7 show that the percentage of turbidity removal in the sedimentation unit is more optimal at the 17 Volt variation. This happens because in this variation, the current density achieved is greater than 15 Volts, turbidity removal more occurred in sedimentation 2 because the volume of the sedimentation 2 unit was greater and the detention time was longer so that the deposition was more optimal. The turbidity removal for the whole process is better at the 15 Volt variation, so the optimal variation is 5 pairs plate and 15 Volts.

4. Conclusion

After researching to reduce turbidity with initial turbidity of 100 NTU by using a communal scale drinking water treatment series with the addition of a plate settler to the sedimentation unit, it can be concluded that the most optimal turbidity removal is at 5 pairs of plates with an electric voltage of 15 volts both at a flow rate of 0.06 Lps and a flow rate of 0.08 Lps with removal of 93.5% and 88.2%, with the final turbidity results were 6.5 NTU and 11.78 NTU, respectively. Adding a plate settler to the sedimentation unit affects the turbidity removal in the sedimentation unit, with total removal of 18.52% at the best variation in the flow rate of 0.06 Lps and 8.65% for the best variation in the flow rate of 0.08 Lps.

References

[1] Kuokkanen V, Kuokkanen T, Rämö J and Lassi U 2013 *Green and sustainable Chemistry* 89-121
[2] Afiatun E, Pradiko H and Prayoga H 2017 *Int. J. GEOMATE* **12** **(34)** 57-61
[3] Pradiko H, Afiatun E and Fabian E 2018 *Indonesian Journal of Urban and Environmental Technology* **1** **(2)** 137-150
[4] Afiatun E, Pradiko H and Fabian E 2019 *Int. J. GEOMATE* **16** **(56)** 123-128
[5] Afiatun E, Notodarmojo S, Effendi A J and Sidarto K A 2018 *Int. J. GEOMATE* **14** **(46)** 32-39
[6] Yustiani Y M and Lidya L 2016 *Procedia Eng.* **154** 353-360
[7] Yustiani YM, Lidya L, Matsumoto T, Rachman I and Komariah I 2017 *Int. J. Eng. Technol.* **9** **(1)** 137-142
[8] Pratiwi A, Yusuf and Gunawan R 2016 *Jurnal Kimia Mulawarman* **13** (1) E-ISSN 2476-9258
[9] Nasrullah M Singh L and Wahid ZA 2012 *Energy and Environmental Journal* **1**

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