

INFLUENCE OF MIXING AND DETENTION TIME IN ELECTRO COAGULATION PROCESS TO TREAT RAW WATER AT BADAQ SINGA WATER TREATMENT PLANT

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INFLUENCE OF MIXING AND DETENTION TIME IN ELECTRO COAGULATION PROCESS TO TREAT RAW WATER AT BADAK SINGA WATER TREATMENT PLANT

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ABSTRACT

Raw water used at Badak Singa Water Treatment Plant come from surface water such as Cisangkuy River. The river is affected by conditions in the upstream, pollution along the stream, climate and weather. In the drinking water supply system, turbidity is the important factor affecting the water treatment efficiency, for several reasons such as aesthetic factor, burden to filtration, and interfere the disinfection process. Electro coagulation is one of water treatment method that combines the process of coagulation, flotation, and electrochemical. **Aims:** This research aims to see at the ability of the electro coagulation process in reducing turbidity as an alternative to substitute the conventional coagulation system.

Methodology and results: This research carried out by testing electro coagulation with variations in mixing, current density produced by voltage 10, 20 and 30 volt, and detention time 5, 10, 20 and 30 minute to reduce the initial turbidity of 100 NTU. The result showed that: the efficiency of electro coagulation with mixing is better than electro coagulation without mixing to reduce the initial turbidity of 100 NTU; the final turbidity value of the processing result is better as the longer of detention time and meet the quality standard from detention time of 10 minute; the higher the current density given and the longer the detention time used, the higher the processing efficiency and the formed flock volume is deposited.

Conclusion, significance and impact study: A good turbidity removal process using electro coagulation requires the agitation process and long detention time.

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KEYWORDS

- Badak Singa water treatment plant
- Electro coagulation
- Electrochemical
- Raw water
- Turbidity

1. INTRODUCTION

The increase of population and rapid economic growth results the increasing of need for clean water (BPLHD Prov. Jabar, 2006). Clean water as main supporting for good health and public welfare is getting more difficult to obtain. An imbalance between the availability of water that tends to decline in quantity and the increasing of water demand coupled with poor water quality is the main cause of the difficulty of getting clean water.

Perusahaan Daerah Air Minum (PDAM) Tirta Wening is a company that handles drinking water needs in Bandung City. One of the company's installation is the Badak Singa Water Treatment Plant (WTP). The raw water used at Badak Singa WTP comes from surface water that are Cikapundung River and Cisangkuy River. Those sources of raw water are affected by conditions in the upstream, pollution along the stream, climate and weather. From time to time those conditions changes affect the surface water quality so that water treatment is required before the water can be used daily. Turbidity is one of the contaminants which becomes the major concern because it often exceeds the quality standards (Alaerts & Santika, 1987).

According to Sawyer and McCarty (1978), in the drinking water treatment systems, turbidity is one key factor for several reasons, such as: aesthetically the water must be free of turbidity, raw water is more difficult to filter when it is turbid and the treatment cost will high if the turbidity is high, and beside the facts that turbidity water contains many harmful organisms that could not be destroyed in the disinfectant process.

To process raw water, WTP Badak Singa requires coagulant (PAC) to bind the turbidity in large amounts, but since there is an uncertainty in raw water quality, the quality of processed water becomes decreased. Therefore, it needs alternative replacement of PAC coagulant with the same efficiency or even more with more affordable cost.

Electro coagulation is an emerging technology that combines the function and advantages of conventional coagulation, flocculation, and electrochemistry in water and waste water treatment (Riyanto, 2013). Electro coagulation mechanisms follow the basic principles used in electrolysis cell systems, where the anodes and cathodes play an important role in the process of oxidation-reduction reaction (Mitiasari, 2015). 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 hydroxyl (Effendi, 2014). Hydroxyl coagulates and flocculates suspended particles are resulted through the process of removal of solids from the water

treated (Kuokkanen et.al. 2013).

This research will examine the ability of electro coagulation method in decreasing turbidity in raw water as an alternative to conventional coagulation system using PAC. The purpose of this research is to analyze the effect of mixing process and detention time on electro coagulation process using aluminum plate electrode to decrease the concentration of turbidity parameters on raw water from Cisangkuy and Cikapundung River which is used by PDAM Tirta Wening Bandung as raw water sources.

2. RESEARCH METHODOLOGY

2.1 Tools and Materials

Component of the research tool consists of: a reactor made of glass with dimensions of 12 cm x 9 cm x 12 cm with a working volume of 1 liter; aluminium plate dimension 7.5 cm x 12 cm x 0.15 cm with plate dimension immersed 7.5 cm x 7.5 cm x 0.15 cm; DC power supply with output voltage 0 - 30 volts; cable and crocodile clip for connecting PSU with plate; Magnetic Stirrer at speed up to 100 RPM which placed in the bottom of the reactor; and flocculator with speeds up to 60 RPM.

The water used in this research is water sourced from Cikapundung and Cisangkuy River water collection pond which has been mixed and taken as raw water. From the laboratory examination obtained an average turbidity value of 100 NTU, so for further research used initial turbidity of 100 NTU of raw water.

2.2 Method

Experiment conducted in the form of determination of current density, influence of mixing, and length of detention time.

The research stages and flow diagram can be seen in Table 1 and Figure 1.

Table 1 Research stages

No	Stages	Aim	Parameters/Tools/Variations
1	Preliminary research	Determination of raw water Parameters	Parameters: Turbidity, Conductivity, Total Disolved Solid (TDS)
2	Research Preparation	- Tool Preparation - Raw Water Preparation	Tools: Reactor, Alumunium Plate, DC Power Supply, Cable, Crocodile Clip, Magnetic Stirrer, Flocculator, Raw Water
3	Main Research	- Determination optimum turbidity removal with or without mixing - Determination turbidity removal detention time	- Variation Voltage: 10, 20, 30 volt - Variation mixing: use and no use mixing - Variation detention time: 5 – 30 minutes

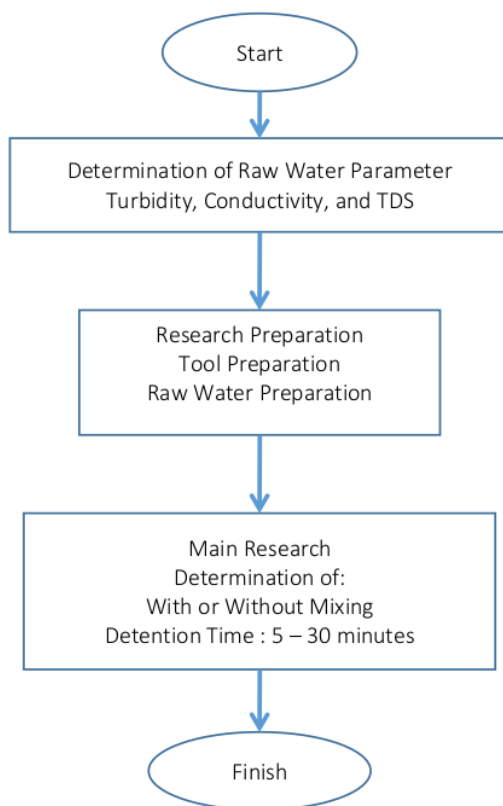


Figure 1 Flow research diagram

2.2.1 Reactor Design

The sketch of sequence of electro coagulation reactor design can be seen in Figure 2.

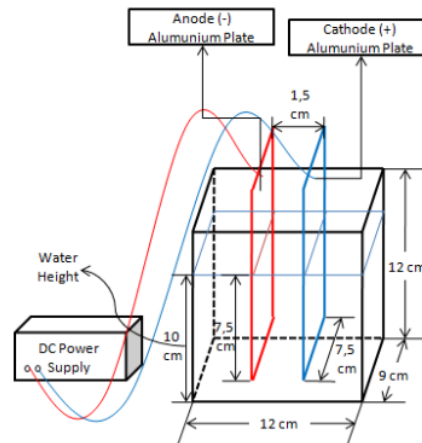


Figure 2 Electro coagulation reactor design

Overall, the design of the reactor to be operated is as follows:

Table 2 Reactor operations

Spesification	Dimension
System Mode	Batch System
Type of electrode	Aluminium Plate
Distance between electrodes	1.5 cm
Voltage	10, 20, and 30 Volts
Detention Time of rapid mixing	5, 10, 20, and 30 minutes
Number of electrodes	One pair
The area of the plate submerged	7.5 cm x 7.5 cm
Rapid mixing, do in reactor	100 RPM, During the electro coagulation process
Slow mixing after rapid mixing, do in flocculator	10 minutes, 60 rpm
Initial turbidity	100 NTU
Sedimentation time after process	15 minutes
The height of the plate from the bottom of the reactor	2.5 cm

The main research mechanisms are: Perform electro-coagulation process with and without mixing during variation 5 - 30 minutes in reactor. Furthermore the treated water is transferred

to the flocculator (jartest) for slow mixing. After that, the water left for the sedimentation process.

2.2.2 Data Collection

Samples are taken at a height of $\frac{1}{2}$ - $\frac{2}{3}$ from the bottom of the reactor and approximately 5 cm from the edge of the reactor using a pipette. Samples are taken every 5 minutes in the range of 5 - 30 minutes. Turbidity Samples were tested using a Lutron turbidity meter TU-2016 model. Samples were taken as much as 10 ml with pipettes to measure the level of turbidity, with aquadest as comparative solution (calibration). The samples were tested for their conductivity using conductivity/TDS meter of Lutron Yk-22Ct model, by dipping the conductivity/TDS meter probe into the reactor at a depth of approximately 5 cm. The value of conductivity is obtained after the digital number reaches a constant value.

2.2.3 Data Analysis

The results of the turbidity of the sample treated by electro coagulation were then compared with the initial turbidity values before the treatment. Electro coagulation performance can be known from efficiency percentage in decreasing turbidity level to meet 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 (Nasrullah et.al., 2012) :

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

Where :

R = Removal efficiency (%)

C_{in} = Influent concentrations (NTU)

C_{ef} = Effluent concentrations (NTU)

3. RESULTS AND DISCUSSION

The electro coagulation studies consisting of: determining the current density, the usage of agitation for mixing process; and the duration of detention.

3.1 Determining The Current Density

By using one pair of aluminum plate with dimension of plate submerged 7.5 cm x 7.5 cm that powered by electricity with 10, 20 and 30 volt variations of voltage and distance between electrode 1.5 cm, obtained current and current density as follows:

Table 3 Current and current density result of each voltage variation

Voltage (V)	Current (A)	Plate Submerged Area (m ²)	Current Density (A/m ²)
10	0.12		21.33
20	0.26	0.005625	46.22
30	0.38		67.56

3.2 Influence of Mixing

In the trial without mixing, the sample in the reactor was electrified with a certain detention time. For the trial with mixing, a series of mixing consisting of two parts, i.e. a rapid mixing during the electro coagulation process with a magnetic stirrer placed in the bottom of the reactor with a certain detention time followed by slow mixing for 10 minutes using a flocculator at 60 rpm (Rezka, 2008). In rapid mixing, the particles will move quickly and provide a great opportunity to come into contact with the electrodes. Whereas in slow mixing, the charged particles will congregate to form flock.

The results obtained on the trial of turbidity variations of 100 NTU are as follows:

Table 4 Comparison efficiency of electro coagulation with and without mixing

Current Density (A/m ²)	Without Pre-Sedimentation		With Pre-Sedimentation	
	Final Turbidity (NTU)	Efficiency (%)	Final Turbidity (NTU)	Efficiency (%)
21.33 A/m ²	6.09	93.91	0.94	99.06
46.56 A/m ²	5.68	94.32	0.79	99.22
67.56 A/m ²	6.94	93.06	0.00	100.00

Under without mixing conditions, suspended solids are settling at the bottom of the reactor, but also appear to float on the surface and hover in the center of the reactor. While in electro coagulation with mixing conditions, flock is settled evenly at the bottom of the reactor. In addition, the results of electro coagulation trials using stirrer has already meet the quality

standard whereas those without mixing still not meet the quality standard. Graphically, the comparison of turbidity removal with mixing and without mixing can be seen in Figure 3.

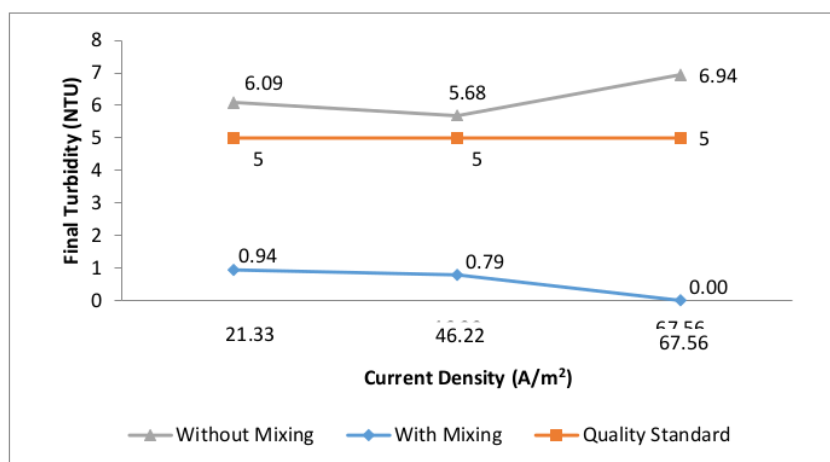


Figure 3 Comparison chart of turbidity removal with mixing and without mixing

Based on Figure 3, it can be seen that the final turbidity of the process with mixing is getting better as the current density increases. However, in without mixing treatment, the effluent turbidity appears random, decreasing at the second current density, and then rising at the third current density.

Graphically, the percentage comparison of the treatment efficiency with mixing and without mixing can be seen in Figure 4.

From Figure 4 it can be seen that the electro coagulation efficiency with mixing is better than electro coagulation without mixing to reduce the 100 NTU initial turbidity. Although in the implementation, the time required for electro coagulation with mixing takes longer because of the addition of 10 minutes of slow mixing time and the required energy is also larger (Novita, 2012). Mixing can speed up the electro coagulation process because turbidity particles will have a great chance to contact with the electrode, so that the formation of charged particles can run faster

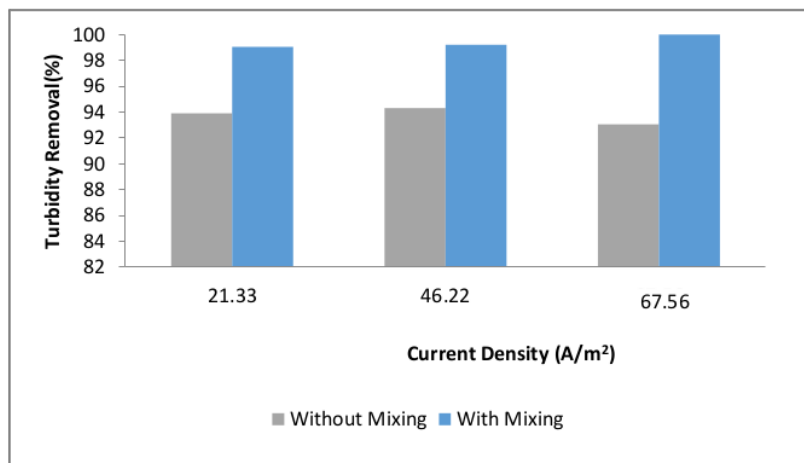


Figure 4 Graph the efficiency of turbidity removal with and without mixing at 100 NTU initial Turbidity

3.3 Determination of Detention Time

This research was also conducted to find the shortest detention time with the best results, both in turbidity removal as well as the quality of flocks that formed. The best efficiency of turbidity removal is seen by comparing the decrease of turbidity in each variation of detention time. The quality of flock formation is seen by measuring the volume of sediment formed at each variation of detention time. The results of this trial will be used as the standard of detention time in the primary research.

3.3.1 Turbidity removal

Turbidity variations used at this research is using initial turbidity of 100 NTU. The turbidity is treated using every variation of current density generated by 10, 20, and 30 Volts with detention times of 5, 10, 20, and 30 minutes. After the research, the results obtained as follows:

Table 5 Efficiency of electro coagulation for every variation time

Initial Turbidity (NTU)	Time (minute)	Curent Density (A/m ²)	Final Turbidity (NTU)	Efficiency (%)
100	5.00	21.33	9.74	90.27
	10.00		2.07	97.93
	20.00		0.94	99.06
	30.00		0.84	99.16
100	5.00	46.22	9.00	91.00
	10.00		1.43	98.57
	20.00		0.79	99.22
	30.00		0.00	100.00
100	5.00	67.56	8.31	91.70
	10.00		0.66	99.34
	20.00		0.00	100.00
	30.00		0.00	100.00

Conditions inside the reactor, it can be said that the coagulation process has worked much better, started at the detention time of 10 minutes. Flock precipitation is formed evenly leaving only a small amount of solids floating in the reactor.

Electro coagulation trials at each detention time meet the quality standards starting at the 10 minutes. Graphically, the turbidity removal at each detention time can be seen in Figure 5.

Based on Figure 5, it can be seen that the result of final turbidity of the electro coagulation process is getting better along with the increasing of detention time used. Turbidity effluent values did not meet the quality standard at 5 min detention time. The turbidity effluent meets the quality standard begins at detention time of 10 minutes. In the 10 minutes until the 30 minutes, the result of turbidity effluent showed no significant difference. Graphically, the percentage of the treatment efficiency can be seen in Figure 6.

From Figure 6 it can be seen that the treatment efficiency already high when starting at the detention time of 10 minutes using the current density from the lowest to the highest. The higher the current density given and the longer the detention time used, the higher the result of treatment efficiency (Al-Abdalaali, 2007), although the difference is not so significant at the 10 to 30 minutes. Electrical voltage affects the formation of a particle charge. The higher the electrical voltage the larger the particle charge. This causes a large charged particle to bind more particles than a particle with a small charge. This is what causes the higher the electrical

voltage, the higher the removal of turbidity.

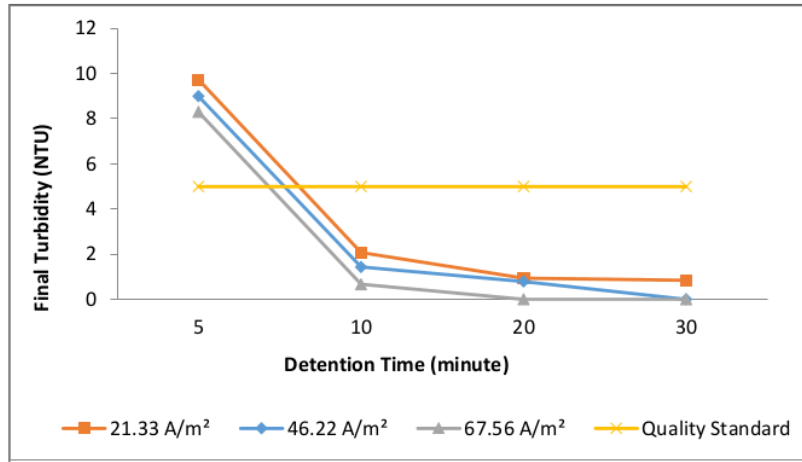


Figure 5 Graph of Turbidity decrease at each current density against detention time

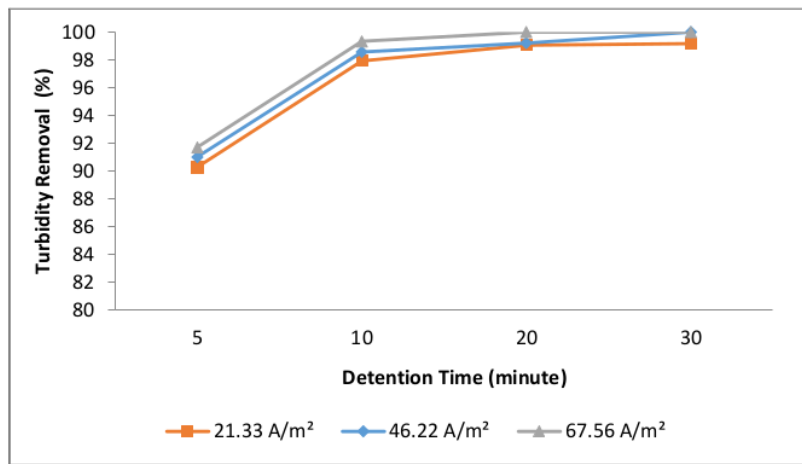


Figure 6 Efficiency of Turbidity removal at each current density

3.3.2 Volume of Sediment

The turbidity used in this trial used a turbidity variation of 100 NTU. The turbidity is treated using any variation of current density generated by 10, 20, and 30 Volt voltages with detention

times of 5, 10, 20, and 30 min. After the trial, the results obtained as follows:

Table 5 Volume of sediment for each variation time

Initial Turbidity (NTU)	Time (minute)	Curent Density (A/m ²)	Final Turbidity (NTU)	Sediment Volume (cm ³)
100	5.00	21.33	9.74	8.10
	10.00		2.07	24.30
	20.00		0.94	56.70
	30.00		0.84	72.90
100	5.00	46.22	9.00	16.20
	10.00		1.43	40.50
	20.00		0.79	81.00
	30.00		0.00	121.50
100	5.00	67.56	8.31	24.30
	10.00		0.66	56.70
	20.00		0.00	97.20
	30.00		0.00	137.70

Based on the observation, the coagulation process did not occur well at 5 minutes of detention time. Suspended solids are seen still hovering in the reactor. The longer the detention time, the formation of the flock looks much better (Sihotang, 2010). It can be seen from the speed of flock formed, stability, and thickness sediment are formed. Optimum conditions began to appear at the detention time of 10 minutes. Graphically, the volume of sediment can be seen in Figure 7.

From Figure 7 it can be seen that the longer the detention time and the higher the current density used, the higher the volume of the formed flock is settled. Therefore, based on the two factors, such as the efficiency of turbidity removal and the thickness of the sediment, it is determined that the detention time is 10 minutes to be used in the main research. The detention time will also affect the level of turbidity removal. The longer the detention time, the greater the likelihood of the particles to join and form the floc, so the better the removal of turbidity reached.

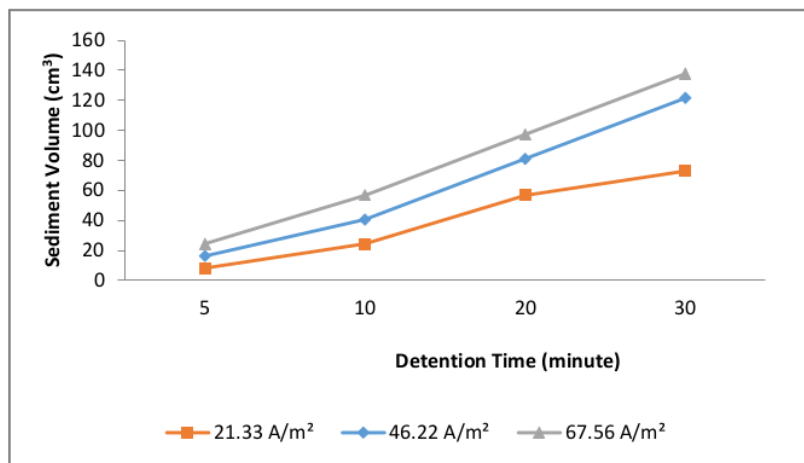


Figure 7 Comparison graph of sediment volume at each detention time

4. CONCLUSION

After testing the effect of mixing and detention time on electro coagulation method for standard water treatment of Tirta Wening PDAM Badak Singa Bandung, can be drawn conclusion: the final turbidity of the treatment results with the mixing is better along with the increasing current density used, while the processing without mixing looks random; Electro coagulation process by using mixing already meet the quality standard whereas if without mixing still not meet the quality standard; efficiency of electro coagulation with mixing is better than electro coagulation without mixing to lower initial turbidity parameter 100 NTU; the final turbidity values of the processing result is improved along with the increase of detention time used and meet the quality standard from detention time of 10 minutes; the higher the current density given and the longer the detention time are used the higher the processing efficiency and the formed flock volume is deposited.

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