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The optimum of detention time on flocculation unit using a laboratory scale prototype

Regita Nurul Anggraeni*

Environmental Engineering, Faculty of Engineering, President University, Jababeka Education Park Jalan Ki Hajar Dewantara, Kota Jababeka, RT.2/RW.4, Mekarmukti, Cikarang Utara, Bekasi, Jawa Barat 17550.

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Abstract. Water used to meet the daily needs of human has different characteristics depending on the quality and amount of substances found in it. Turbidity can performance the quality of the water. The raw water used in this research comes from Kalimalang River. Coagulation and flocculation is one of the most improtant processes to remove the substances in raw water. Detention time is the main parameters for flocculation process. **Objectives.** This research aims to find out the optimum of detention time in flocculation prototype unit. **Methods and result.** Designing and assembling the flocculator lab-scale prototype using 20 cm of pipe diameter. Running the prototype and analysis the effect of detention time to the clarified water turbidity in 30 minutes of 1 Liter imhoff cone with raw water range 41-60 NTU in a long dry season. The result is the optimum clarified water turbidity is found in the 19,7 minutes detention time appropriate to the 41-60 NTU raw water turbidity range. **Conclusion.** The result shows, that the optimum detention time was obtained in 19,7 minutes for 41-60 NTU raw water turbidity range.

* Corresponding author: regitanurul13@gmail.com

1 Introduction

Water is the most important elements in the world and is need to support our daily activities. Water used to meet the daily needs of humans has different characteristics depending on the quality and amount of substances found in it, which inevitably influence the type of treatment required before it can be used properly[1]. There are many water sources that can be used such sea, river, lake until ground water. The water must undergo a treatment process before it can used because it is pollutants contain. The process called as water treatment process, a process or system that is carried out to treat the water source into the clean water that can be used for daily activities and where it should be compliance with the standards[2]. Such changes in conditions affect the quality of the surface water from time to time so that water treatment is needed before daily use of the water. Turbidity is one of the most important pollutants because it often meets the quality standards[3].

Water turbidity is caused by suspended matter such as clay, silt, finely divided organic and inorganic matter, soluble organic colored compounds, planktons and other micro and macroscopic organisms[4]. Turbidity can be used to known the performace of treatment processes also an overall water treatment system[4]. One of the most generally used processes to remove turbidity in water in the form of suspended and colloidal material is the addition of coagulants and flocculants such as alum, ferric chloride, and long-chain polymers[4].

According to SNI 6774 : 2008 about Planning Procedures for Water Treatment Installation Package Units, there are several processes that must be in a drinking or clean water treatment, it is screening, coagulation, flocculation, sedimentation and filtration[5]. Coagulation is a process of adding chemical compounds called coagulant to destabilize colloids or particles in raw water usng rapid mixing to form the large particles. The Poly Aluminum Chloride (PAC) is the coagulant that is often used in this process bacause it more susceptible to hydrolysis and can form a floc faster and has a large coagulation power to produce stable floc[6]. Flocculation is a slow mixing process to homogenous floc that have been destabilized in coagulation process into larger and more solid so that they can be easily settled[7]. Sedimentation is a process to separate large floc with the clean water to produce clearer water using by gravity [6]. The next process is filtration that aimed at filtering water through sand media from chemical, physical and biological sedimenation[2].

According to Mc Kenzie (2002), coagulation and flocculation are the important process of conventional water treatment system because this process can remove the microorganism, bacteria and other infectious agents[8]. The coagulation and flocculation process contributes significantly to the entire process because it is posibble to get the clean water more quickly because larger particles can be removed in the initial process[9].

Coagulation is the process of destabilizing colloid particles so the particles growth can occur as a result of particle collosion. The water source entering the coagulation process contains a lots of bacteria, such as natural organic matter (NOM) that has a negative charge[8]. The percentage removal of natural organic matter (NOM) affects the efficiency of the treatment of drinking water[10] and it is important to neutralize the negative charge by adding the positive charge such as Poly Aluminm Chloride (PAC) as a coagulant.

Flocculation is a process using slow mixing to homogeneous the particles that already destabilize to become floc that can be precipitate to the next process[7]. According to Raidah (2018), flocculation is a process of adding flocculants by slow mixing to increase the interrelationships between particles, so it increasing the union[7]. The flocculation process has several parameters that must be considered with SNI 6774 : 2008 about Planning Procedures for Water Treatment Installation Package Units and the others references in Table 1.

Table 1. Comparison of design criteria for flocculation process

Source	Parameters		
	Detention Time (minutes)	Velocity gradient /G (s^{-1})	Number of tank (pcs)

SNI 6774 : 2008	30-45	60-5	6-10
Mc Kenzie Book	20-30	80-20	Min. 3
Crittenden Book	Min. 20	40-30	-

According to EPA (2011), detention time is a measure of the average amount of time that a liquid stays in a water retaining system obtained by dividing the volume of the tank by the significant of flow rate[12]. The gradient of velocity can be considered as the amount of shear that takes place, the higher the value of G, the more intense the mixing takes place or the relative velocity o fthe two particles or distance of the fluids[8].

The above parameters may affect the quality of water such as turbidity, so parameters will affect each other. The coagulation-flocculation relationship is very strongly related. It will affect water quality if detention time does not meet the standards, namely clarified water turbidity. If the detention time from the set standard is too short, then there is no proper formation of floc or solids. Conversely, if the detention time is too long, solids or floc that have formed may break again. This has to do with what has been explained in the coagulation-flocculation process, if the zeta-potential value is close to zero, then the particles will attract each other and form larger particles and remove it.

This research will create a lab-scale prototype design for the flocculator unit by adjusting the predetermined design criteria. Then, the purpose of this study was to find the optimum of detention time on the flocculation process in the clarified water turbidity parameter. Raw water to be used is from the Kalimalang River.

2 Method

This research is the initial part of the overall research framework that dedicated for certain range in raw water turbidity (41-60 NTU).

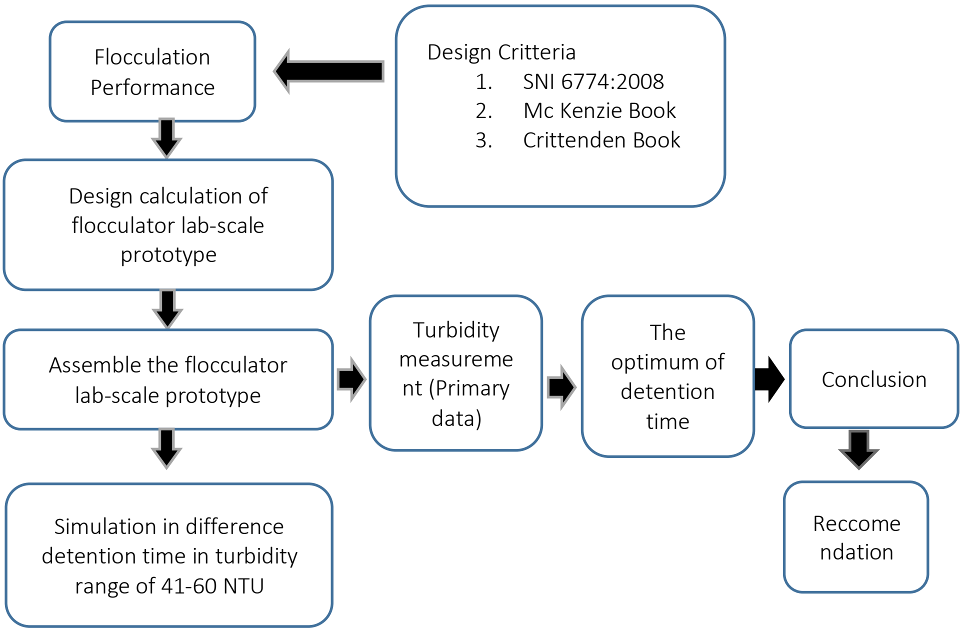

Fig 1. Research framework

3 Results and Discussion

3.1 Design Prototype of Flocculator Unit

The calculation of making the prototype design which refers to the design criteria of SNI 6774 : 2008 dan other references. In this calculation, the researcher was maintains the velocity gradient and flow rate as a fixed parameters. The purpose of maintains the parameters is to find the value that according to the design criteria that was detention time.

Table 2. Calculation sheet of making flocculator prototype

Item	Sources	1	2	3	4	5	Reservoir
Velocity Gradient (1/s)	Design	55	45	35	25	15	5
Radius tank (m)	Design	0,1	0,1	0,1	0,1	0,1	0,1
Surface area (m2)	Design	0,0314	0,0314	0,0314	0,0314	0,0314	0,0314
Average Flow Rate (m3/s)	Measurement	0,0000522	0,0000522	0,0000522	0,0000522	0,0000522	
Height of tank (m)	Design	0,45	0,37	0,32	0,30	0,28	
Water volume (m3)	Calculation	0,01413	0,011618	0,010048	0,00942	0,008792	
Detention Time (s)	Calculation	270,9	447,3	462,2	362,3	1006,5	
Detention Time (min)	Calculation	4,5	7,5	7,7	6,0	16,8	
Accumulation Detention Time (min)	Calculation	4,5	12,0	19,7	25,7	42,5	
Viscosity (kg/m/s)	Reference	0,000862	0,000862	0,000862	0,000862	0,000862	
Gravity (m/s2)	Reference	9,8	9,8	9,8	9,8	9,8	
Density (kg/m3)	Reference	996	996	996	996	996	
Headloss (m)	Calculation	0,07	0,08	0,05	0,02	0,02	

The velocity gradient value used in this prototype is 55 s^{-1}, 45 s^{-1}, 35 s-1, 25 s^{-1} and 15 s^{-1} using 5 tanks for flocculation and 1 tank as a reservoir. The value of velocity gradient and number of tanks was followed the SNI 6774 : 2008 guidelines which states is 60-5 s^{-1} and number of tanks is 6-10 pcs with the flow rate used was 0,00005222 m^3/s according to the measurement.

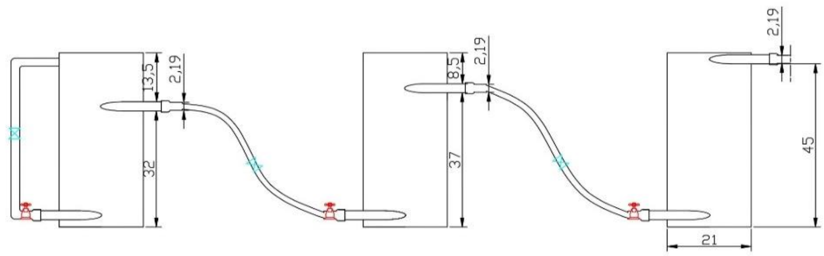

Fig 2. Flocculator prototype design, tank 1-3 from right to left (Side view)

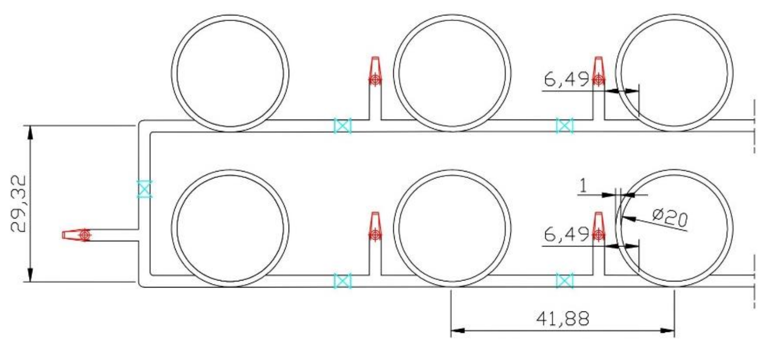

Fig 3. Flocculator prototype design, tank 1-6 from right below to right above (Front View)

This is a lab-scale prototype design with a pipe diameter of 20 cm and has a different height or inlet between tank 1 and other tanks due to differences in height commonly referred to as the headloss. The prototype was created with a parallel system due to imited site conditions.

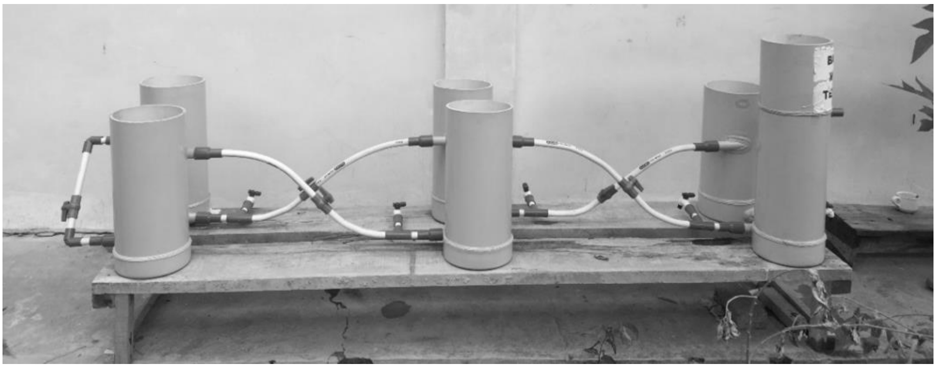

Fig 4. Flocculator prototype

After the prototype was design, it was simulated using raw water from Kalimalang River. This research was carried out for a long dry season in October 2019. Range of raw turbidity in that time is 41 until 60 NTU. Raw water used in this experiment has been given a coagulant, Poly Aluminum Chloride (PAC) with a range of 14-70 ppm based on daily report of Water Treatment Plant 2. The results are analyzed using imhoff cone with 30 minutes precipitation in 1 Liter of sample[13]. The water from 30 minutes of precipitation called clarified water turbidity. The data taken were raw water turbidity and clarified water turbidity. The flocculator lab-scale prototype does not use a mixer, so it uses only a hydraulic jump system.

Data is collected for 1 week on weekdays for different detention time in each number of tanks with a measurement time span of 30 minutes once in 4 hours/day. Turbidimeter that used in this research is 2100Q Portable Turbidimeter (Figure 7).

Fig 5. Turbidimeter that used in research

3.2 Data analysis

Total data collection for the range of raw water turbidity 41-60 NTU is 29 data for all number of tanks on Table 3.

Table 3. Result of analysis

Detention Time (Minutes)	Raw water turbidity	Clarified water turbidity
12	55,6	9,03
	47,4	9,11
	49,5	10,1
	56,4	10,3
	55,4	10,5
	57,8	10,7
	50,5	11,6
	43,2	12
Average		10,4
Detention Time (Minutes)	Raw water turbidity	Claified water turbidity
19,7	40,4	7,35
	44,9	8,49
	40,7	8,81
	52,9	8,92
	54,9	9,02
	56,2	9,27
	54,6	10,4
	40,2	11,1
	56,6	11,3
	50	11,7
	58,2	13,2
Average		10,0
Detention Time (Minutes)	Raw water turbidity	Clarified water turbidity
25,7	58,5	9,02
	45,2	12,8
	41,5	13,3
	51,4	13,8
	43,6	16,2

Average		13,0
Detention Time (Minutes)	Raw water turbidity	Clarified water turbidity
42,5	49,2	8,88
	42,6	10,8
	56	11,7
	42,4	12,8
	40,9	16,2
Average		12,1

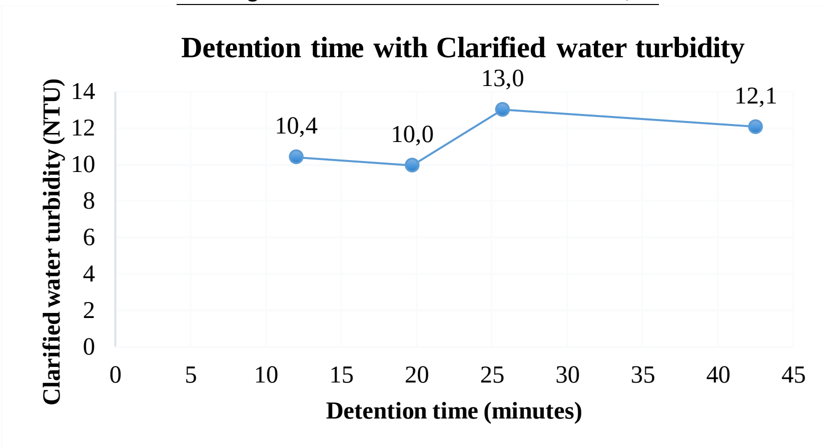

Fig 6. Detention time effects to clarified water turbidity

From the results of the study, it can be seen in Figure 8, that optimum clarified water turbidity is found in a 19,7 minutes detention time appropriate to the 41-60 NTU raw water turbidity range. On clarified water turbidity was 10 NTU, the detention time is 19,7 minutes.

Detention time according to SNI and other references shows that the optimum detention time is 20-45 minutes, while research using a prototype lab-scale indicate that the optimum detention time is 19,7 minutes. According to John Wiley and Son (1979), floc settlement mechanism, which is the contact formed by particles with higher settling velocity combined with particles with lower settling velocity, resulting in greater settling velocity and faster settling time[14].

According to Pradiko,Afiatun and Fabian (2018), the research by without mixing and the detention time is 10 minutes in flocculation process and 100 NTU or raw water, the result were 5,68 until 6,94 NTU for the final turbidity because under mixing condition, the suspended solids settle at the bottom of reactor but also appear to float on the surface and remain in the reactor center. But, if used the electro coagulation with mixing, it will better to reduce the 100 NTU raw water than without mixing condition because the mixing will speed up the chance of interaction between the particles[3].

4 Conclusions

From this research, it can be concluded, for flocculation performance with turbidity level indicators. Flocculation laboratory scale prototype used parallel train (3-2) that determined by the design criteria that refers to SNI 6774:2008. The velocity gradient were 55 s^{-1}, 45 s^{-1}, 35 s^{-1}, 25 s^{-1}, and 15 s^{-1} with 0,0000522 m^3/s for the flow rate. The optimum of detention time in the range of raw water turbidity 41-60 NTU was 19,7 minutes.

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