THE USE OF A STATIC MIXER FOR THE COAGULATION UNIT IN THE DUREN SERIBU II WATER TREATMENT PLANT

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Abstract

In the drinking water treatment plant involves a significant component i.e., coagulation, which distributed coagulants vastly and equally through rapid stirring for destabilizing colloids and suspended particles in the raw water. In water treatment plants, coagulation units are often classified into mechanical and hydraulic coagulation. This study aimed to discover the use of and in-line static mixers as coagulation in designing the Duren Seribu II Drinking Water Treatment Plant (WTP). The design criteria for coagulation unit in Duren Seribu II WTP was determined by comparing several data obtained from literature studies and evaluation of the existing conditions of Duren Seribu I WTP. Duren Seribu I WTP was evaluated by direct measurement in the field. From the results of data analysis, the design criteria appropriate for Duren Seribu II WTP, the G value is 2078.07 sec^{-1}, the detention time (td) is 4 sec, and the G.td value is 8352.19.

Keywords: *coagulation, drinking water, Duren Seribu II WTP, water treatment plant*

Introduction

Along with the population growth in Depok City, it will increase the water demand therefore the development of drinking water services are necessary. A way to conform the increasing water demands is developing a water treatment plant (Reynold & Richard, 1996). Based on RISPAM or Master Plan for Drinking Water Supply for Depok City, it is planned to develop Duren Seribu II WTP with capacity of 150 L/sec that uses Angke River as raw water source to increase the service coverage of Depok City (RISPAM Kota Depok, 2020). The WTP is planned to be built in Bojongsari District, Depok City that met the Indonesian standard drinking water quality requirements according to the Regulation of the Minister of Health Republic of Indonesia Number 492 of 2010.

On the time being, a 100 L/sec WTP named Duren Seribu I is operated to fullfil the existing water demand. It is located at Sawangan Elok Street Number 10, Duren Seribu, Bojongsari, Depok. Consider the existing WTP withdrawn its raw water from Angke River which will be used as raw water resources for the new WTP, therefore the Duren Seribu I WTP is used as a reference for design the new Duren Seribu II WTP. The existing Duren Seribu I WTP is a conventional water treatment plant consists of coagulation, flocculation, sedimentation, rapid sand filtratrion, and disinfection units. It uses in-line static mixer as coagulation unit.

The coagulation unit is a significant component in drinking water treatment, as mixing

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Received: 20 February 2023
Revised : 7 March 2023
Accepted: 30 March 2023
DOI: 10.23969/jcbeem.v7i1.7260

coagulants is dispersing coagulant uniformly throughout the basin and allowing contact between the colloids particles and coagulant for destabilizing colloids particles in raw water (Kawamura, 1991). By the time the water leaves this unit, the coagulation process has progressed sufficiently to form microfloc.

Various types of coagulation units may be generally classified as (i) mechanical coagulation uses mechanical equipment as impeller and turbine mixers, paddle mixers, by a motor with the help of electricity (Reynold & Richard, 1996), and (ii) hydraulic coagulation with gravity force as hydraulic jump, and in-line static mixers (Qasim, 2000). The degree of mixing is based on the power imparted to the water that measure as velocity gradient, considering that more input power creates greater turbulence, and greater turbulence lead to better mixing.

$$G = \sqrt{\frac{P}{\mu \times V}} \qquad (1)$$

Where G is velocity gradient (sec^{-1}), P is mixing power (watt), V is volume (m^3), μis dynamic viscocity (kg/m.s). As shown in the Equation (1), the value of G depends on the power input, the fluid viscocity, and the basin volume. The velocity gradient also related to the shear forces in the water; thus, larger velocity gradients produce appreciable shear forces. G value in-line static mixer are shown in Table 1.

The degree of mixing completion is dependent on the velocity gradient and the value of G.td, whereas td is the detention time. The magnitude of the dimensionless parameter G.td is related to the vigorous of the mixing during coagulation (mixing intensity) (Gabrielle et al., 2021). G.td value has a range of 600-10.000 (Davis, 2010).

Table 1. Design Criteria Coagulation In-Line Static Mixer

Parameter	Design Criteria	Source
Detention Time (td)	1-5 sec	(Davis,2010)
Velocity Gradient (G)	>750 sec^{-1}	(Davis,2010)
G.td Value	600-10.000	(Davis,2010)

In general, hydraulic coagulation depend on the head differential that provides hydraulic turbulence to achieve the desired velocity gradient. Static mixers are principally identified by their lack of moving parts. Typical examples include in-line static mixer, which is a type of rapid mixing which occurs in a standard pipe diameter that equipped with plates/elements that causing sudden changes in the velocity patterns as well as momentum reversals. It can break up the flow and increasing turbulence.

The advantage of using an in-line static mixer is that there are no moving parts, and no external energy sources are needed. Thus, mixing using an in-line static mixer is quite effective and the coagulation of an in-line static mixer does not require a large area (Davis, 2010). The in-line static mixer is the most compact method and is increasing in popularity. It is found that in-line static mixer is used in 65 L/sec Sindang Pasekan water treatment plant (Arief et al., 2020) and 290 L/sec Kaligarang III water treatment plant (Lestari et al., 2019).

The power consumed by static-mixing devices can be computed using the following equation.

$$P = Q \times h_L \times \rho \qquad (2)$$

Where P is mixing power (watt), Q is flow rate (m^3/sec), h_L headloss (m), ρ is water density (kN/m^3).

Headloss dissipated as liquid passes through in-line static mixer can be calculated according to the graph that determining pipe diameter and head loss per element, as shown in Figure 1. Mixing ratio of 1.5 is usually used in the design. (Davis, 2010).

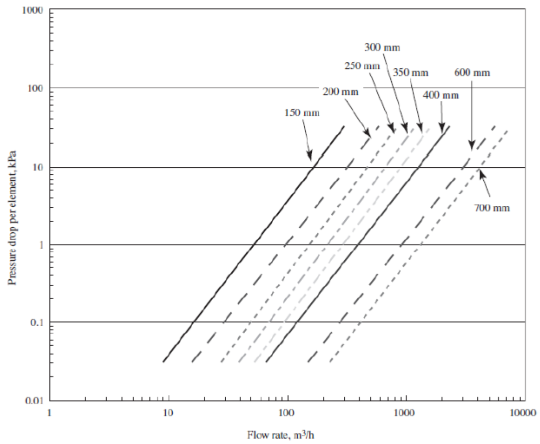

Figure 1. The Graph of Determining Pipe Diameters and *Headloss* per Element.

h_L = Total of elements × h_L per element (3)

The pipe length (L) of in-line static mixer can be obtain as follows.

L = Total of elements x mixing ratio x pipe diameter (4)

Research Methodology

The design of the coagulation unit for Duren Seribu II WTP consists of several stages:

a. Evaluation the performance of in-line static mixer which is used in the existing Duren Seribu I WTP, as follows:

Data collection:

- Inventory of pipeline from intake to flocculation unit (length and diameter).
- Measure the pumping head in the intake.
- Measure the pressure as shown in the manometer inserted after the static mixer.

Performance evaluation:

- Calculate headloss occuring in the static mixer using the head differential between pumps and manometer.
- Evaluate mixing power (P), velocity gradient (G), and G.td value.

b. Literature review,

The literature review was conducted to provide such a useful information in the design of coagulation unit of Duren Seribu II WTP, i.e:

- Guidelines for water treatment pant design,
- The condition of the planning area,
- Related researchs in the area of mixing and coagulation.

c. Design of coagulation unit, as follows:

- Jartest analysis to select the proper coagulant and determine its doses.
- Evaluate and select the value of velocity gradient (G), time detention (td), and G.td.
- Spesify pipe diameter from intake to flocculation unit that fullfil the velocity requirement.
- Calculation of the headloss occurs in the in-line static mixer using graph developed by Davis (2010) as shown in Figure 1.
- Calculate the required length of in-line static mixer using equation (4).

Results and Discussion

Existing Coagulation at Duren Seribu I WTP.

In designing a WTP, it is necessary to reference an existing WTP for estimating (i) the water treatment unit that can be used, (ii) the water treatment process can be operated optimally, to produce water that meets the quality of drinking water. The evaluation performance of the coagulation unit carried out at Duren Seribu I WTP with a design capacity of 250 L/sec. The schematic of coagulation unit Duren Seribu I WTP can be seen in Figure 2.

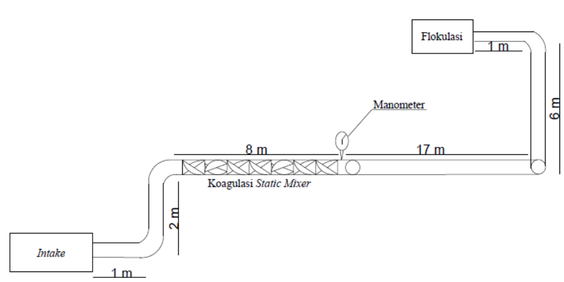

Figure 2. Schematic of Coagulation Unit of Duren Seribu I WTP.

The type of coagulation used by the Duren Seribu I WTP is in-line static mixer, where this system does not use a machine, but uses a plate that causes mixing power. The coagulant used by the Duren Seribu I WTP is aluminum sulfate with a dose of 30.68 mg/L. Aluminum sulfate coagulant that has been diluted will be injected to the coagulation unit using a dosing pump.

The coagulation in-line static mixer at Duren Seribu I WTP has a diameter of 400 mm and a pipe length of 8 m. The head of pump at the intake is 30.8 m, and the manometer measurement is 24 m. Thus, the headloss value obtained on the static mixer pipe is 6.77 m or equivalent to 0.677 bar.

The volume in the in-line static mixer is 1 m^3 with a discharge at the time of observation of 50 L/sec which is less than design capacity of 250 L/sec. This existing operational condition gives detention time (td) value of 20.10 second. The mixing power (P) can be estimated using water density value of 996.81 kg/m^3 and headloss of 6.77 m as mentioned above, resulted the mixing power of 3324.32 Nm/sec. Then, it followed by resulted the value of G (velocity gradient) = 1944.94 sec^{-1} and G.td = 39,086. The detention time (td) and G.td value obtained have not met the design criteria of Davis (2010).

In spite of that, the quality of the water produced based on tubidity parameter found in the reservoir of Duren Seribu I WTP is 0.74 NTU. It shows that the existing WTP has fulfilled the drinking water standard according to the Minister of Health Republic of Indonesia Number 492 of 2010 based on turbidity parameter below 5 NTU. In the existing conditions, the td and G.td values in coagulation do not conform the design criteria. However, it does not cause problems during operation because the flocs that were formed are quite large and dense. Accordingly, the in-line static mixer of Duren Seribu I WTP is adopted as coagulation unit in the new Duren Seribu II WTP.

Design of Coagulation Unit at Duren Seribu II WTP.

The schematic of coagulation unit Duren Seribu II WTP can be seen in Figure 3, where the 400 mm diameter with 17.95 m pipe length transmit water from intake to flocculation unit. The in-line static mixer has a diameter of 400 mm and length of 5 m.

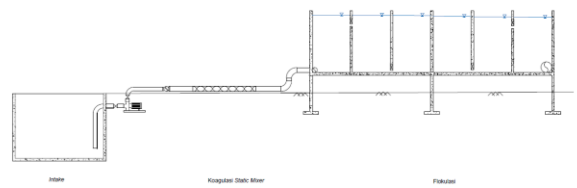

Figure 3. Schematic of Coagulation Unit Duren Seribu II WTP.

Calculation the in-line static mixer dimensions starts with calculating the headloss value. Based on the graph of the pressure drop for pipe diameters between 150 mm to 700 mm (used 400 mm), discharge of 540 m^3/h, resulting in headloss value of each element is 2 kPa = 1.02 m, as shown in Figure 4.

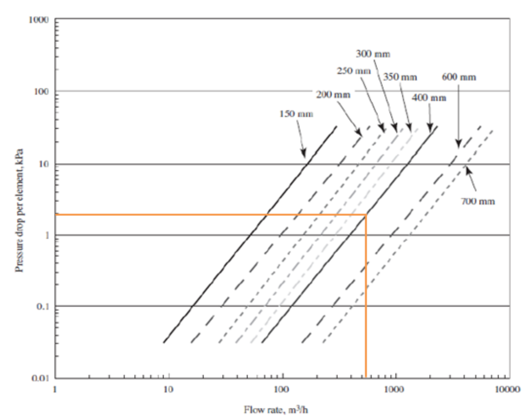

Figure 4. The Pipe Diameters and Headloss per Element for Q 150 L/sec or 540 m^3/h

Total headloss (h_L)

h_L = Total of element × h_L per element

= 8 × 2 kPa

= 16 kPa = 1.63 m

The lenght of static mixer (L)

L = 8 × 1.5 × 0.40 m

= 5 m

Volume static mixer (V)

$$V = \frac{1}{4} \times \pi \times D^2 \times L$$

$$= \frac{1}{4} \times 3.14 \times (0.4\ m)^2 \times 5\ m = 0.60\ m^3$$

Detention time (td)

$$td = \frac{V}{Q} = 4\ sec$$

The detention time (td) obtained meets the design criteria of Davis, 2010 and several researchs related to the coagulation in the pipe, i.e 5.4 sec is found in Sindang Pasekan WTP (Arief et al., 2020), and 5.2 sec is used in Kaligarang III WTP (Lestari et al., 2019).

Mixing power (P) imparted in this static mixer is calculated using equation (2) above:

$$P = 0.15\ m^3/sec \times 1.63\ m \times 9987\ kN/m^3$$

$$= 2442\ kW$$

The velocity gradient (G) resulted can be calculated using equation (1), i.e.:

$$G = \sqrt{\frac{2442\ W}{9.38 \times 10^{-3}\ kg/m.sec \times 0.60\ m^3}}$$

$$= 2078.07\ sec^{-1}$$

G.td value = 2078.07 /sec × 4 sec

= 8352.19

The resulted velocity gradient is within the range of the existing Duren Seribu I WTP i.e. 1944.94 sec^{-1} and 3183.09 sec^{-1} is found in Solear WTP (Ramdhan et al., 2019).

G.td value obtained has met the design criteria of Davis, 2010 with a range of 600-10000 and similar to Cipageran WTP that resulted 6746.6 as its G.td value (Sani et al., 2019).

The proposed design of coagulation unit Duren Seribu II WTP can be seen in Figure 5. Coagulant to be used is aluminum sulfate that consistent with the existing Duren Seribu I WTP. The jartest experiment with Al_2O_3 content of 17% results an optimum dose of 15 mg/L which is twice the average dose of the existing Duren Seribu I WTP i.e 30.68 mg/L of aluminum sulfate that contain 5% of Al_2O_3.

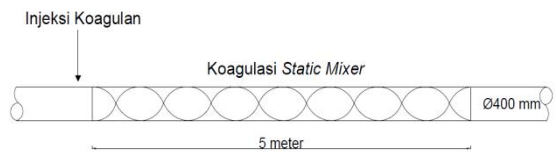

Figure 5. Coagulation Plan Design

Based on the existing Duren Seribu I experience above, an average dosages of 30.68 mg/L aluminum sulfat (5% Al_2O_3) will be added to the new Duren Seribu II WTP.

Conclusions

Based on the Duren Seribu I WTP performance evaluation, it can be concluded that several design parameters do not meet the design criteria standard such as the detention time (td) and G.td value in the coagulation in-line static mixer. Nonetheless, the production water has fulfilled as the quality of drinking water standard according to the Regulation of the Minister of Health Republic of Indonesia Number 492 of 2010. Therefore, the evaluation of existing parameters in Duren Seribu I WTP can be used as a reference for planning a new water treatment plant Duren Seribu II.

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