Technical evaluation of ultrafiltration unit in Siwalanpanji's water treatment plant, PDAM Sidoarjo

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Abstract. Raw water with high turbidity requires pretreatment on its ultrafiltration unit to prevent fouling. Based on that, it is necessary to evaluate the ultrafiltration unit's quality, quantity, and operation in Siwalanpanji's WTP. The evaluation method compares the design criteria, technical specification, and ultrafiltration with the conventional to see the existing condition. The results of ultrafiltration turbidity and organic substance efficiency removal are about 53% and 18%, it's not more good than conventional unit efficiency removal, which has 89% for turbidities removal and 37% for organic substance removal. Moreover, the quality of the production water fulfills the standards of Indonesia Health Minister No. 492 of 2010, except for the value of organic substances, which is in this analysis it around 13.69 mg/L meanwhile, in standard, it must not be more than 10 mg/L. Evaluation of the operating performance of each treatment unit related to the membrane unit at the WTP in Siwalanpanji has fulfilled the criteria design. However, using an ultrafiltration unit results in treated water quality is equivalent to a conventional treatment unit. So from this evaluation, it is found that there is a need for recommendations pretreatment, which is better for raw water to treat before ultrafiltration.

1. Introduction
One of WTP in PDAM Sidoarjo is in Siwalanpanji. There are five water treatment installations Siwalanpanji's WTP, water treatment consisting of 4 conventional installations in the form of packages, and one installation with ultrafiltration (UF), interconnected and its production capacity up to 165 L/s. For the process and operation of the ultrafiltration unit at the Siwalanpanji's WTP, the processing unit used consists of intakes, collecting wells, pre-sedimentation, and collector tanks. The raw water used at the Siwalanpanji's WTP is water that comes from Wilayut ricefields sewer. Based on research, the water quality of Siwalanpanji's WTP in 2019 has a BOD value of 5.78 mg/L, COD 2.3 mg/L, and TSS 35.94 mg/L [1]. Based on this, it is informed that the raw water contains COD and BOD, which exceeds the class 1 water quality standard in Indonesia Government Regulation No. 22 of 2021, where this regulation is the quality standard used for raw water to be used for drinking water in Indonesia.

An ultrafiltration membrane unit is a unit that can be operated as a single operation which means that the unit does not require pretreatment unless there is a screen filter or operated in combination with other processes such as coagulation and adsorption [2]. In cases where the raw water used has a high level of turbidity or high levels of pollution, the use of conventional water treatment (adsorbs, coagulation, oxidation) at the beginning is very helpful in increasing the efficiency of the performance of the ultrafiltration unit [3]. In water treatment using membranes, pretreatment is also one way to reduce
fouling [4]. In the absence of pretreatment, adequate can cause fouling to occur more quickly and often, which will make the membrane unit break down quickly.

Based on these, it is necessary to identify the quality of raw water and production water compared to the existing quality standards, along with an evaluation of the operating performance of the installation related to the ultrafiltration unit at the Siwalanpanji Water Treatment Plant (WTP) of PDAM Sidoarjo compared to the design criteria. So that it can be known the conditions that exist in the water treatment installation, and from the evaluation results can contribute information/identification and recommendations to improve the operating performance of the Siwalanpanji's WTP PDAM Sidoarjo.

2. Methodology

2.1. Research data collection

The data used in the analysis of raw water and production water quality of the Siwalanpanji WTP are:

2.1.1. Primary data. Primary data was obtained from sampling at 5 points at the research location: wells as raw water sample, outlet pra-sedimentation, outlet ultrafiltration, and production water in the reservoir. This 5 points location can be seen in Figure 1. The samples will analyze for six parameters: pH, turbidity, colour, residual chlorine, organic substances, and e.coli.

2.1.2. Secondary data. The secondary data required are the water treatment system at the site, the dimensions of the WTP unit, the quality of raw and production water, and the ultrafiltration unit's specifications.

2.2. Data analysis and discussion

The data that has been collected will be analyzed and discussed as a whole then the results are compared with the results established by quality standards and design criteria in the literature. The analysis and discussion are carried out so that the results of the data processing process can be compared with the concepts and theories that underlie the scope of research obtained from the literature study. The first step is to evaluate raw water quality with Indonesia Government Regulation No. 22 of 2021 and production water by comparing it with the existing quality standards in the Minister of Health RI No.492 of 2010. After that, analyzing the parameter values of the water outlet installation, then evaluate the operating performance of each installation to find out the performance of the installation that does not meet the design criteria from various literature, besides that it also evaluates the operating costs of the
installation performance by comparing the overall WTP operating costs and membrane operating costs. So from this evaluation, a recommendation for the operating performance of the ultrafiltration membrane unit at the Siwalanpanji's Water Treatment Plant (WTP) can be achieved. The evaluation method matrix can be seen in Table 1.

Table 1. Matrix of data analysis and discussion method.

| Evaluation Parameter | Method Used |
|----------------------|-------------|
| Raw water and production water quality | Compared with the existing quality standards in Indonesia Government Regulation No. 22 Of 2021 for raw water and the Indonesian Minister of Health Regulation No. 492 of 2010 for production water |
| Performance of installation unit | Compared with design criteria and literature |
| Performance of ultrafiltration unit | Compared production volume and washing water volume of membrane units and compared ultrafiltration membrane installations with conventional treatment units |
| Operation cost for membrane | Compared between WTP cost operation overall and membrane operating cost |

3. Result and discussion
The treatment plant at Siwalanpanji WTP consists of 5 conventional installations and one installation using an ultrafiltration membrane (UF). Currently, only four conventional installations operate at the Siwalanpanji WTP (5 L/sec, 10 L/sec, 2x25 L/sec, and 50 L/sec) and one installation with an ultrafiltration membrane (UF). The conventional installation at the Siwalanpanji WTP is a package installation where the 50 L/s and 2 x 25 L/s installations contain a coagulation-flocculation unit, a sedimentation unit, and a rapid sand filter unit inside. As for the 5 L/s and 10 L/s installations, it is more apparent. The flow of the processing process can be seen in Figure 2.

The treatment process at the Siwalanpanji WTP, in general, is as follows, raw water originating from intake flowed to the collecting well 1 and continued to the collection well 2. Then from the collecting well, it flowed into the pre-sedimentation tank. In the pre- sedimentation tank, PAC coagulant was added. After that, the treated water goes to the collection tank. Before entering the equalization tank, it is pre-chlorinated with chlorine gas. Water is then pumped from the equalization tank to 4 conventional installations and ultrafiltration (UF) installation. Water from conventional installations of 50 L/s and 2 x 25 L/s is collected first to the WTP reservoir. Then the flow converges back into the main reservoir, where it is carried out post-chlorination, which is optional based on the water conditions in the reservoir.
Figure 2. The flow of Siwalanpanji's water treatment plant production process in general.

3.1. Water quality evaluation
Two data are used to analyze water quality, namely primary data and secondary data, from which the data is then analyzed. Based on the results of the analysis of water samples, then an evaluation of the treatment building unit related to ultrafiltration at the Siwalanpanji WTP PDAM Sidoarjo was carried out.

3.1.1. Primary data analysis. Primary data comes from laboratory analysis. In this study, the water samples are from raw water samples, production water samples, pre-sedimentation outlets, ultrafiltration outlets, and conventional outlets.

a. Raw water analysis
The raw water quality analysis results are compared with Indonesia Government Regulation No. 22 of 2021 concerning the quality of class I water bodies used for drinking water. Analysis of raw water quality can be seen in Table 2.

| Parameter | Unit            | Analysis Results | Quality Standard of Raw Water for Drinking Water (Indonesia Government Regulation No. 22 of 2021) |
|-----------|-----------------|------------------|-------------------------------------------------------------------------------------------------|
| pH        |                 | 7.4              | 6.9                                                                                             |
| E.Coli    | MPN/100 mL      | ≥1600            | 1000                                                                                            |

Based on Table 2, for the value of raw water quality compared to PP No 22 Tahun 2021, with the compared values being the pH and E. coli parameters, it is known that the results of the analysis of raw water for the pH value fulfil the quality standard while for E. coli it does not fulfil the quality standard, which is stated in Indonesia Government Regulation No. 22 of 2021.

b. Production water analysis
The production water which used in this analysis is from water that has complete treatment Siwalanpanji's WTP. Result of analysis of production water quality compared to Indonesian Minister of Health Regulation No. 492 of 2010. Analysis of production water quality can be seen in Table 3.
Table 3. Results of production water analysis at Siwalanpanji’s water treatment plant.

| Parameter           | Unit  | Analysis Results | Quality Standards (Indonesian Minister of Health Regulation No. 492 of 2010) |
|---------------------|-------|------------------|---------------------------------------------------------------------------|
| pH                  |       | 7.3              | 6.5 – 8.5                                                                  |
| Colour              | TCU   | 9.3              | 15                                                                         |
| Turbidity           | NTU   | 1.43             | 5                                                                          |
| Remained Chlor      | mg/L  | 5.32             | 250                                                                        |
| Organic Substance   | mg/L  | 13.69            | 10                                                                         |
| (KMnO₄)             |       |                  |                                                                            |
| E.Coli              | MPN/100 mL | 0               | 0                                                                          |

Based on Table 3, for the quality value, the production water compared to Indonesian Minister of Health Regulation No. 492 of 2010 has met the applicable quality standards except for the parameter value of organic substances (KMnO₄). The analysis results show that the average value of organic substances (KMnO₄) is 13.69 mg/L while the standard quality value is 10 mg/L. Based on research that the presence of rain on dry agricultural land and residential area is the largest contributor to the potential for erosion that will cause siltation in the river and reduce the amount of discharge area, it can also increase the turbidity in river water [11].

c. Outlet pre-sedimentation water analysis

Result of outlet pre-sedimentation unit compared to the raw water used in the Siwalanpanji’s WTP. A comparison table of results from outlet Pre-sedimentation units and raw water can be seen in Table 4.

Table 4. Comparison of raw water quality and outlet pre-sedimentation.

| Parameter           | Unit       | Raw Water | Outlet Pre-sedimentation |
|---------------------|------------|-----------|--------------------------|
| pH                  |            | 7.4       | 7.8                      |
| Colour              | TCU        | 144.3     | 90.7                     |
| Turbidity           | NTU        | 47.7      | 2.4                      |
| Remained Chlor      | mg/L       | 0         | .95                      |
| Organic Substances  | (KMnO₄)    | 27.4      | 17.9                     |
| E.Coli              | MPN/100 mL | ≥1600     | 33.7                     |

This comparison can show the percentage of removal efficiency in the pre-sedimentation unit at the Siwalanpanji WTP. Based on Table 4, the pre-sedimentation unit’s removal efficiency is high. The efficiency of removing turbidity is 95%, organic matter is 35%, and E. coli 97.5%, even though the results outlet from this pre-sedimentation unit do not fulfill the quality standards of drinking water standards because the presedimentation unit is one of the pretreatment units, but the percentage efficiency removal for turbidity and E. coli is high. It is because there is coagulant adding and pre-chlorination in these pretreatment units.

d. Ultrafiltration and conventional outlet water comparison analysis

Result of outlet ultrafiltration unit and outlet conventional units compared to the Indonesian Minister of Health Regulation No. 492 of 2010. Quality analysis for outlet ultrafiltration units and outlet conventional units can be seen in Table 5.
Table 5. Quality results for outlet ultrafiltration and conventional unit.

| Parameter          | Unit  | Results     | Quality Standart (Indonesian Minister of Health Regulation No. 492 of 2010) |
|--------------------|-------|-------------|--------------------------------------------------------------------------|
|                    |       | Outlet UF  | Conventional                                                              |
| pH                 |       | 7.7        | 7.4                                                                      | 6.5 – 8.5 |
| Colour             | TCU   | 24.7       | 15.7                                                                     | 15        |
| Turbidity          | NTU   | 1.13       | 0.45                                                                     | 5         |
| Remained Chlor     | mg/L  | 0          | 2.4                                                                      | 250       |
| Organic Substances | mg/L  | 14.75      | 17.4                                                                     | 10        |
| (KMnO₄)            |       | 2.7        | 0                                                                        | 0         |

Based on Table 5, the water quality value produced between outlet ultrafiltration and conventional units is graphed. That graph can be seen in Figure 3. The quality analysis results of outlet ultrafiltration and conventional units compared to Indonesian Minister of Health Regulation No. 492 of 2010 have complied with the applicable quality standards except for the value of colour parameters and organic substances (KMnO₄). However, outlet ultrafiltration unit in the results of this analysis, the value of E. coli also does not meet the quality standard.
Figure 3. Graph of quality analysis results of outlet ultrafiltration and conventional unit.

From the results of the primary data analysis, it can be seen the efficiency of the allowance for the building unit, which can be seen in Table 6. In Table 6, the presentation of efficiency used is turbidity and organic matter.

| No. | Installation Unit | Parameter          |
|-----|-------------------|--------------------|
|     |                   | Turbidity | Organic Substance |
| 1   | Pre-sedimentation | 95%       | 35%               |
| 2   | Ultrafiltration   | 53%       | 18%               |
| 3   | Conventional      | 89%       | 37%               |

The efficiency results, which can be seen in Table 6, show that the efficiency value for the ultrafiltration unit is not better than conventional, where the turbidity removal value of the ultrafiltration unit is lower than that of the outlet conventional. The comparison used in this study is the conventional 50 L/second units, where this conventional unit consists of a coagulation-flocculation unit, sedimentation, and rapid sand filter. This difference in efficiency may be due to a lack of pretreatment in the ultrafiltration unit, wherein water treatment using the ultrafiltration unit at the Siwalanpanji's WTP outlet from the pre-sedimentation is directly feed to the ultrafiltration unit. As for conventional units, there are still pretreatments, such as the addition of chemicals.

Based on research, ultrafiltration technology can remove more than 80% turbidity and colour 35-50% [5]. However, ultrafiltration technology cannot reject TDS (Total Dissolved Solid) properly because UF can only reject small molecules, hardness and viruses [6]. Also, in the treatment of drinking water using ultrafiltration, there is an essential requirement for its application, namely the need for the addition of chemicals such as coagulants or carbon powder at the beginning of the treatment to remove/reduce smaller contaminants such as natural organic matter or micropollutants [7]. Pretreatment for water that enters this membrane is also a way to reduce fouling which can cause a decrease in the performance of the membrane [4].

3.1.2. Secondary data analysis. Secondary data was obtained from the laboratory at the Siwalanpanji WTP PDAM Sidoarjo, from the existing data obtained water quality parameters used by each building unit, including pH and turbidity. The latest data obtained is data from 2020. The available graphic data is taken from averaged secondary data each day which is so that the figures for the parameters of turbidity and pH are obtained every month.

a. Raw water analysis

The raw water quality analysis results are compared with PP No. 22 of 2021 concerning the quality of class I water bodies as water used for drinking water. The graph of secondary data analysis of raw water quality can be seen in Figure 4. Based on Figure 4, it is known that the turbidity of raw water is relatively high between 5-50 NTU with an average pH of 7.4.
b. Production water analysis

The analysis of production water quality compared with Indonesian Minister of Health Regulation No. 492 of 2010. The graph of secondary data analysis of production water quality can be seen in Figure 5. Based on Figure 5, it is known that the quality of produced water has fulfilled the quality standards of Minister of Health RI No. 492 of 2010 for turbidity and pH parameters, with mean turbidity value 0.75 and pH 7.1.

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**Figure 4.** Graph of secondary data analysis of raw water quality in January – December 2020 at Siwalanpanji’s water treatment plant.

**Figure 5.** Graph of secondary data analysis of production water quality in January – December 2020 at Siwalanpanji’s water treatment plant.
In addition, there are secondary data from the literature. The PJT I Environmental Laboratory analysis results for the average value of raw water quality used at the Siwalanpanji WTP can be seen in Table 7.

**Table 7.** Secondary data quality of raw water average values in Siwalanpanji's water treatment plant.

| Parameter       | Unit  | Average Value | Quality Standard (PP No 22 Tahun 2021) | Quality standard information                      |
|-----------------|-------|---------------|----------------------------------------|--------------------------------------------------|
| Temperature     | °C    | 29.07         | Dev 3ª                                 | Difference temperature with air above surface water |
| pH              | mg/L  | 6.86          | 6-9                                    | minimal                                          |
| DO              | mg/L  | 2.89          | 6                                      | minimal                                          |
| BOD             | mg/L  | 5.78          | 2                                      | minimal                                          |
| COD             | mg/L  | 26.3          | 10                                     | minimal                                          |
| TSS             | mg/L  | 35.94         | 40                                     | minimal                                          |
| NO₃N            | mg/L  | 1.02          | 10                                     | minimal                                          |
| NO₂N            | mg/L  | 0.29          | 0.06                                   | minimal                                          |
| NH₃N            | mg/L  | 0.36          | 0.1                                    | minimal                                          |
| PO₄P            | mg/L  | 0.1           | 0.2                                    | minimal                                          |
| Oil & fat       | mg/L  | 1.09          | 1                                      | minimal                                          |

Source: Laboratorium Lingkungan PJT I [1]

notes: ³ Deviation from the average temperature of the last five years

Based on Table 7, the value of raw water quality at the Siwalanpanji WTP, the parameters that meet the quality standards are temperature, pH, TSS, NO₃N, and PO₄P. Meanwhile, the other parameters do not fulfil the quality standards Indonesia Government Regulation No. 22 of 2021 for water used as raw water for drinking water.

### 3.2. Evaluation of installation performance related to the ultrafiltration membrane unit

The units evaluated include collecting well units, pre-sedimentation units, and collection tanks. From the evaluation, the effectiveness of the performance of the treatment units will be known and provide suggestions for units that do not meet the design criteria so that not only does the water quality fulfil the quality standards, but the treatment unit also meets the design criteria.

#### 3.2.1. Wells

Collector wells are helpful for the temporary storage of water from intake, and then the water will pump to a pre-sedimentation unit or an existing conventional package unit. At the Siwalanpanji's WTP PDAM Sidoarjo there are 2 interconnected wells. The results of the evaluation of the well unit can be seen in table 8. The following describes the data regarding the construction of the well:

- Diameter (d) = 4.85 meter
- Depth (t) = 5 meter
- Flow (Q) = 175 L/s = 0.175 m³/s

Time detention calculation as follows.

- Volume (V) = \( \frac{\pi}{4} \times d^2 \times t \)

  Volume (V) = \( \frac{3.14}{4} \times 4.85^2 \times 5 \)
  = 92.33 m³

- Td = \( V / Q \)
  = 92.33 m³ / 0.175 m³/
  = 527.58 s
\[ = 8.79 \text{ minutes} \]

**Table 8. Calculation of well performance parameters.**

| Installation unit | Parameter        | Results | Design Criteria | Description |
|-------------------|------------------|---------|-----------------|-------------|
| Collecting Well   | Time Detention   | 8.79    | < 10 minutes    | fulfil      |

Source: *Schulz & Okun, 1984 [8]*

Based on the evaluation results, it was found that the detention time in the well is 8.79 minutes. It met the design criteria of the well.

3.2.2. **Pre-sedimentation.** Pre-sedimentation tanks at the Siwalanpanji's WTP are post-water treatment intake after the well. In this unit, there are 12 units in one building. This pre-sedimentation tank in February 2021 changed the operational system. There are two other tanks in the pre-sedimentation building, namely an aeration tank and biological treatment using bio-ball. The use of aeration tanks and bio-balls is to improve yield outlets from the sedimentation basin. The results of the evaluation of the pre-sedimentation unit can be seen in Table 9. The following is data on pre-sedimentation units:

- Flow (Q) = 175 L/sec = 0.175 m³/sec
- Length (p) = 15.5 m
- Width (l) = 5.5 m
- Depth (t) = 5 m
- Number of tanks = 12
- T = 29°C
- \( v \) = 8.21 \times 10^{-7} m³/sec
- g = 9.81 m/sec
- Sg = 2.65
- Particle size (d) = 0.2 mm
- \( \rho \) = 995.97 kg/m³
- \( \mu \) = 0.8181 \times 10^{-3} N.sec/m²

**Calculation of the performance parameters of the pre-sedimentation unit:**

- Q each tank = 0.015 m³/s
- Volume each tank = \( p \times l \times t \)
  \[ = 15.5 \times 5.5 \times 5 \]
  \[ = 426.25 \text{ m}^3 \]
- Td = \( V/Q \)
  \[ = \frac{426.25 \text{ m}^3}{0.015 \text{ m}^3/s} \]
  \[ = 28.416 \text{ sec} \]
  \[ = 7.89 \text{ hours} \]
- So = \( \frac{\text{Debit}}{\text{Surface area}} \)
  \[ = \frac{0.015 \text{ m}^3/s}{85.25 \text{ m}^2} \]
  \[ = 0.000176 \text{ m}^3/\text{m}^2.\text{sec} \]
  \[ = 0.63 \text{ m}^3/\text{m}^2.\text{h} \]
- Vh = Q/Ac
  \[ = 0.015 \text{ m}^3/s/(5.5 \times 5) \text{ m}^2 \]
  \[ = 5.5 \times 10^{-4} \text{ m}^3/\text{s} \]
- R = (l x t) / (2t + l)
  \[ = 1.7 \text{ m} \]
- Nre = \( \frac{\rho \times R \times V \times S}{\mu} \)
\[
N_{re} = \frac{99597 \times 1.77 \times 5.5 \times 10^{-4}}{0.8181 \times 10^{-3}} = 1185
\]

\[
N_{fr} = \frac{\frac{V}{h^2}}{\frac{g \times R}{\rho}} = \frac{(5.5 \times 10^{-4})^2}{9.81 \times 1.77} = 1.7 \times 10^{-8}
\]

**Table 9.** Calculation of pre-sedimentation unit performance parameters.

| Installation unit | Parameter                  | Results        | Design Criteria | Description |
|-------------------|----------------------------|----------------|-----------------|-------------|
|                   | Ratio length and width     | 1 : 3          | 1 : 5           | fulfil      |
| Pre-sedimentation | Time detention             | 7.89 hours     | 1.5 – 3 hours   | fulfil      |
|                   | depth                      | 5 m            | 3 – 5m          | fulfil      |
|                   | Surface area               | 0.63 m³/m² . hours | 0.83 – 2.5 m³/m² . hours | fulfil |
|                   | Reynold number             | 1185           | 2000            | fulfil      |
|                   | Horizontal velocity        | $5.5 \times 10^{-4}$ m/s |                      |             |
|                   | Fraud number               | $1.7 \times 10^{-8}$ | $10^{-5}$      | unfulfilled |

Source: Schulz & Okun, 1984 [6]

Based on the evaluation results of the pre-sedimentation unit, the results, the comparison of length and width, detention time, depth, surface load, and Reynold number are obtained under the existing design criteria. Meanwhile, the fraud number does not fulfil the design criteria.

3.2.3. *Equalization tank.* The equalization tank at the Siwalanpanji’s WTP serves as a temporary collection of the results of the pre-sedimentation, which will then be pumped and distributed to the next unit, namely the ultrafiltration unit other conventional units. The results of the evaluation of the collection tank unit can be seen in Table 10. The following describes the dimensions of the collection tank:

- Lenght (p) = 9 meter
- Width (l) = 6 meter
- Depth (t) = 4 meter
- Flow (Q) = $175$ L/s = $0.175$ m³/s

**Table 10.** Calculation of equalization tank performance parameters.

| Installation unit | Parameter  | Results   | Design Criteria | Description |
|-------------------|------------|-----------|-----------------|-------------|
| Equalization tank | Time detention | 20.5 minute | < 10 minute     | unfulfilled |

Source: Schulz & Okun, 1984 [6]

Time detention calculation for equalization tank as follows.

- Volume (V) = p x l x t
  = $9 \times 6 \times 4$
  = $216$ m³

- \(T_d = \frac{V}{Q}\)
  = $216$ m³ / $0.175$ m³/s
  = $1234.28$ s
  = $20.5$ minute
Based on the evaluation results, the detention time in the well is 20.5 minutes. It does not meet the design criteria, but the difference in detention time is not a problem because of the pump system in the equalization tank.

3.3. Evaluation of ultrafiltration unit

There are two skits of ultrafiltration units at the Siwalanpanji's WTP that are used. Each skit consists of 36 ultrafiltration tube modules. The ultrafiltration used at the Siwalanpanji's WTP comes from the Deerfos membrane by type Hollow-Fiber Membrane Module type DFU-0870AD. Based on the manufacturer's specifications of the membrane, the operating conditions used are as follows.

- Max. Inlet Pressure (kPa) = 300
- Max Operating TMP (kPa) = 200
- Max. Temperatur (°C) = 40
- pH = 2 – 9
- filtrate turbidity (NTU) = < 0.1

The following specifications regarding the membrane module used:

- Effective surface area (m²) = 70
- Design Flux (m³/hours) = 2.8 – 8.4
- Dimension (ϕ x Hmm) = 216 x 2.275
- Membrane material = PVDF
- Pores size = 0.07 µm

The following is the data regarding the ultrafiltration unit:

- Flow (Q) = 30 L/s
- Total module = 36 module

Ultrafiltration technical parameter calculation:

- Flow each module = Q/total module = 30 L/s / 36 = 0.83 L/s = 2.9 m³/hours
- Membrane fluks = \( \frac{V}{t} \) = \( \frac{2.98 \, m^3}{1 \, hour} \) = 2.98 m³/hours
- Wash water volume = \( \frac{wash \, water}{production \, water} \times 100\% \) = \( \frac{0.24 \, m^3/day}{2592 \, m^3/day} \) = 0.01%

Based on the evaluation results of the membrane flux value that meets the criteria of the membrane itself, the percentage of membrane washing water volume is 0.01%. The results of the evaluation of the ultrafiltration unit can be seen in Table 11.

**Table 11. Calculation of ultrafiltration unit performance parameters.**

| Installation unit | Parameter       | Results         | Design Criteria | Description |
|-------------------|----------------|----------------|----------------|-------------|
| Ultrafiltration   | Fluxes          | 2.98 m³/hours  | 2.8 – 8.4 m³/hours | fulfil      |
|                   | Wash water volume | 0.01%         |                |             |

Source: Deerfos membrane Catalog
3.4. Performance analysis of ultrafiltration unit at Siwalanpanji drinking water treatment plant (WTP) PDAM Sidoarjo

This study made an operational comparison between the ultrafiltration unit and the conventional 50 L/second units. From the results of this comparison, the effectiveness of using the ultrafiltration unit at the Siwalanpanji WTP will be known. The operational comparison used is the percentage of membrane washing water and filter washing water. In the previous discussion, it is known that the percentage of membrane washing water is 0.01%, while for water, the percentage of filter washing water is as follows.

- Backwash water volume = 28.08 m³/hours
- Filtration duration of each filter = 40 hours
- Production water volume = filtration rate x filtration duration = 21.31 m³/hours x 40 hours = 852.43 m³/day
- Backwash water presentation = \( \frac{\text{backwash water volume}}{\text{water production volume}} \times 100\% \) = \( \frac{28.08 \text{ m}^3/\text{day}}{852.43 \text{ m}^3/\text{day}} \times 100\% \) = 3.29%

A comparison of the calculation results of the percentage of wash water can be seen in Table 12.

| Installation Unit | The volume of production water | The volume of wash water | percentage of wash water |
|-------------------|-------------------------------|-------------------------|-------------------------|
| Membran UF        | 2592 m³/day                   | 0.24 m³/day             | 0.01 %                  |
| Conventional filter | 852.43 m³/day               | 28.08 m³/day            | 3.29 %                  |

Based on the percentage of washing water used compared to produced water, the use of UF membranes is more effective because the volume of washing water used is small compared to the volume of water produced by the ultrafiltration membrane unit, which is 0.01%. The conventional unit requires a volume of washing water that is more when compared to the volume of water produced, which is 3.29%.

Then, compare the energy required for membrane operations with the energy for the overall operation of the Siwalanpanji WTP. A comparison of energy requirements is obtained from the energy requirements of the pumps used. It can be seen in the pump specs. Eight pumps are needed in the operation of the entire unit at the Siwalanpanji WTP, as shown in Table 13. Based on Table 13, it is known that the UF pump has significant enough power compared to the power used for the entire WTP, which is 33% of the total power required.

| Utilization | Type | Capacity (L/s) | Power (KW) |
|-------------|------|----------------|------------|
| Intake pump | EBARA P 0127844 | 50 | 11 |
| WTP pump    | Grundfos OPQ8220174 | 80 | 37 |
|             | Grundfos NK 125 - 250 / 269 | 100 | 75 |
|             | AH - F - B - BAOE |
| UF pump     | Ebara 150X125 FSLA | 50 | 55 |
|             | EBARA 100x80 FSJA | 25 | 30 |
|             | Ebara 150X125 FSLA | 50 | 55 |
|             | Ebara 150X125 FSLA | 50 | 55 |

3.5. Recommended operation performance of ultrafiltration membrane unit

Based on the analysis of existing conditions and supported by primary data. The results outlet conventional with pretreatment addition after the pre-sedimentation unit, namely coagulation-
flocculation and sedimentation, has a better outlet quality than outlet ultrafiltration which has a pre-sedimentation unit for its pretreatment. Based on this, it is known that the operation of the ultrafiltration unit is not good because it is incomplete pretreatment existing. Hence, it needs to be held pretreatment before entering the ultrafiltration unit. The flow chart for processing recommendations can be seen in Figure 6.

**Figure 6.** Flowchart of processing recommendations using ultrafiltration.

In the flow chart, it is explained for pretreatment. What will be done is coagulation-flocculation and then enters the sedimentation tank. Procurement of buildings for coagulation-flocculation so that the concentration of colloids remaining in the water can be reduced so that the performance of the UF membrane is not heavy and fouling does not occur frequently. Based on research, the coagulation-flocculation process using PAC before ultrafiltration can increase turbidity removal efficiency up to 99% [9]. In addition, the use of PAC can also increase the efficiency of removing humic acid organic matter by up to 90% compared to not using PAC only 40% [10].

Based on the flow chart of alternative processing, it can inform that the coagulation-flocculation and sedimentation processes are carried out before entering the UF. In addition to this, the addition of coagulant is also done before entering each WTP. So that the production process flow becomes, after the water collection tank will be divided into 5, namely, to the coagulation-flocculation and sedimentation unit before entering the UF, to the WTP unit 5 L/s, WTP 10 L/s, 50 L/s, and 2x25 L/s. WTP 5 L/s and 10 L/s are clarator. Before entering the WTP, coagulant will be added first, and for WTP 50 L/s and 2x 25 L/s, whose units are packaged WTP with coagulation-flocculation sedimentation and rapid sand filters. The step to add coagulant that mentions before is more effective because it avoids adding excessive coagulant as in the previous processing where there were two times the addition of coagulant, namely pre-sedimentation and before entering WTP. The difference in the description of the addition of coagulant after the performance recommendation can be seen in Figure 7.

**Figure 7.** The flow of the Siwalanpanji's production process in general after adding recommendation units.

4. Conclusion

Water quality from unit ultrafiltration is not fulfilled the water quality standard, with a parameter value of colour is 24.7 TCU, the organic substance is 14.75 mg/L, and some of E. Coli 2.7 MPN/100 mL, which is the standard quality for each parameter are 15 TCU, 10 mg/L and E. Coli 0 MPN/100 mL. Then, turbidity and organic substance efficiency removal are about 53% and 18%, so there is a need for
the advanced process after unit ultrafiltration. Besides that, the ultrafiltration unit at the Siwalanpanji's WTP obtained a flux value that met the factory criteria. Then, it found that the UF unit was more efficient with washing water needed was 0.01%. As for the energy required, reach out 33% of the total energy requirement of the entire installation in Siwalanpanji. Water quality parameters of organic substances do not meet the specified quality standards, so there is a need for an advanced process.

Acknowledgements
The author would like to thank the supervisors and lecturers for the final project and all parties who completed this research. Besides that, the author would like to thank the Director of the PDAM Sidoarjo, the Head of the Production Section, the Head of the Laboratory Section, and the PDAM Operator for providing the data and facilities needed during this research period.

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