Selection Of Design Criteria For The Coagulation, Flocculation And Sedimentation Unit In The Klapanunggal Drinking Water Treatment Plant

Fathimah Hanun Syifaun Jannah, Riana Ayu Kusumadewi, R. Ratnaningsih

Abstract : The purpose of this study is to obtain a design criteria that can be used to design Klapanunggal Water Treatment Plant (IPAM). The design criteria are necessary for designing a drinking water treatment plant, hence the water treatment process runs optimally and can produce water that fulfills Indonesian drinking water standard, namely PerMenkes No. 492 of 2010. The Klapanunggal IPAM development design refers to the existing condition of Gunung Putri IPAM, considering that the raw water quality of the Gunung Putri IPAM is almost the same with the raw water IPAM Klapanunggal. Determination of design criteria for Klapanunggal IPAM is done by comparing several data obtained from the literature study on the design criteria of the textbook and literature study on research journals that discuss the IPAM evaluation and the results of the Gunung Putri IPAM performance evaluation. Upon the evaluation of the Gunung Putri IPAM, direct measurements of the plant dimentions was carried out to calculate the performance of coagulation, flocculation, and sedimentation units, and evaluation of the production water quality: From the results of the data analysis, the design criteria that will be used for IPAM Klapanunggal, the G value is 822/sec for the coagulation unit, 54-22 /sec for the flocculation unit; detention time (td) value is 8 seconds for the coagulation unit, 18 minutes for the flocculation unit, and 78 minutes for the sedimentation unit; Gtd value is 39,000; So value is 5.6 m³/m³/hour; Reynold number (Nr) value is 12.7; Froud number (Nf) value is 1.06 x 10⁻⁶.

Index Terms: coagulation, design criteria, IPAM evaluation, Flocculation, production water quality, sedimentation

1. INTRODUCTION

As the population increase, water demand also increase because without water humans cannot live their lives. On the other hand, population growth also decreasing the quality of water in raw water sources due to human activities and land use around the source. In fulfilling water demand for the community, water treatment is needed. At each water treatment unit has design criteria that regulate some designing of drinking water treatment plant that have an effect on the process of drinking water treatment, so that the water treatment process runs optimally and can produce quality water. This drinking water treatment refers to the Indonesian drinking water standard, namely the Minister of Health No. 492 of 2010 concerning Drinking Water Quality Requirements covering chemical, biological and physical requirements. [19] In this study a performance and operation evaluation was carried out on the Gunung Putri Water Treatment Plant (IPAM), Bogor Regency as a reference IPAM to obtain the design criteria to be used in the designing of the IPAM Klapanunggal. Gunung Putri IPAM is used as a reference IPAM because it has the same raw water quality as the raw water quality that will be used by IPAM Klapanunggal.

From the results of the evaluation, several parameters in the coagulation, flocculation and sedimentation units did not meet the existing design criteria, but the quality of the treated water had met the quality of drinking water. From this problem, a comparison of data from the literature study of the design criteria was compared to the Gunung Putri IPAM evaluation, with the aim to obtain design criteria for designing the IPAM Klapanunggal plant. Coagulation is a charge destabilization process in suspended particles and colloids, particles cannot settle on their own, the deposition of these flocks formed by the addition of coagulants as electrolytes absorbed by colloidal particles so that the charge of the particles becomes neutral [2]. The detention time of coagulation is < 60 minute.[19] Flocculation is a slow stirring unit that occurs immediately after a rapid stirring process is carried out. This slow stirring will increase the chance and number of collisions between particles. The degree of stirring must be large enough so that the floc remains suspended and moves, but this power is also not too large which can cause the outbreak of the formed floc. [24]. The detention time of flocculation is 10-60 minute.[6] In general there are 4 stages of the floc formation process, namely the stage of colloid destabilization, the phase of micro-floc formation, the phase of micro-floc incorporation and the stage of floc macro formation. [21] Sedimentation or precipitation is the separation of particles that are in the water by gravity. The presence of particles in water is measured by looking at turbidity or by directly measuring the weight of the dissolved solid [4]. The detention time of sedimentation is min. 4 minute.[12]

2. MATERIAL AND METHODE

This study was conducted to evaluate the performance of equivalent IPAM, namely Gunung Putri IPAM was conducted from February 2019 to March 2019. The data needed in this study include primary data and secondary data. The primary data itself is the result of the evaluation of Gunung Putri IPAM which covers the calculation of the performance of the coagulation unit, flocculation, and sedimentation, actual discharge data Gunung Putri IPAM, and measurement of production water quality from Gunung Putri IPAM. For secondary data itself obtained from literature studies on the criteria for the design of coagulation, flocculation and sedimentation units and literature studies of previous studies regarding evaluating the performance of IPAM in Indonesia.
Primary data collected can be seen in Table 1.

Calculate the performance of coagulation, flocculation and sedimentation units consisting of (1) detention time (td), (2) velocity gradient (G), (3) Gtd, (4) Surface loading (So), (5) Reynold number (NRe), and (6) Froude Numbers (NFr) using the formula:

\[ td = \frac{v}{Q} \]  

\[ G = \sqrt{\frac{p}{\mu \times V}} \]  

\[ Gtd = G \times td \]  

\[ So = \frac{Q}{A} \]  

\[ N_{Re} = \frac{v \times p \times R}{\mu \times V} \]  

\[ R = \frac{1}{2} \times \text{distance between plate/tube settler} \]  

\[ N_{Fr} = \frac{Vp^2}{R \times g} \]

3 RESULT AND DISCUSSION

3.1 Evaluation of Gunung Putri IPAM

The selection of a water treatment unit in an IPAM based on the quality of the raw water itself. In designing an IPAM, it is necessary to have the reference existing IPAM, so that it can estimate the water treatment unit that can be used and further can be used to estimate the quality of water from the results of existing IPAM processing. In designing the IPAM Kapanunggal, it is designed to use the Cileungsi river raw water. Based on the quality of raw water in the Cileungsi River, Gunung Putri IPAM which uses raw water sources from the Cikeas River has the same raw water quality as the Cileungsi River. So, a comparison of the data on the quality of water from the Cileungsi River and the Cikeas River to the drinking water quality standards of the Minister of Health Regulation 492 of 2010. [16] From the comparison water quality data of the Cileungsi River and Cikeas River, it is known that there are some parameters that do not meet drinking water quality standards based on the Minister of Health Regulation 492 of 2010 concerning drinking water quality standards, which can be seen in Table 2. It is known from data Table 2., that turbidity, fecal coliform, and total coliform parameters do not meet drinking water quality standards based on Minister of Health Regulation No.492 of 2010 concerning Drinking Water Quality Standards, so it is necessary to process them in advance to produce production water that fullfill drinking water quality standards. In this study, water quality measurements were also carried out, namely turbidity parameters at the coagulation inlet and sedimentation outlet to determine the performance of each water treatment unit. The Average turbidity measurement data in February-March 2019 can be seen in Table 3.

\[ N_{Re} = \frac{v \times p \times R}{\mu \times V} \]  

\[ R = \frac{1}{2} \times \text{space between plate/tube settler} \]
standards based on Minister of Health Regulation No.492 of 2010 concerning Drinking Water Quality Standards.

3.2 Analysis of Design Criteria
Analysis of this design criterion is done by comparing some data obtained from the literature study regarding the design criteria of the textbook and literature study on previous research that discusses the IPAM evaluation as well as data on the performance evaluation of Gunung Putri IPAM. This design criteria analysis is carried out to determine the design criteria that will be used by the IPAM Klapanunggal IPAM plan. The evaluation of Gunung Putri IPAM itself was carried out by observation and measurement in the field to obtain data related to the condition of each Gunung Putri IPAM building unit. The data in question are the number of units, dimensions, methods, and capacities in each unit of coagulation, flocculation, and sedimentation. This data will be used to evaluate existing conditions against design criteria.

3.2.1 Coagulation
In designing the Klapanunggal IPAM the type of coagulation that will be used is hydraulic coagulation with Aluminum sulfate coagulant. Analysis of the comparison of design criteria parameters can be seen in Table 4.

From the analysis of the coagulation unit, for the parameter td to be used as the design criteria is the value of Gunung Putri IPAM of 8 seconds, because the value still meets the comparison range of existing data and has the same raw water characteristics as the IPAM Klapanunggal raw water. The smaller the td value the better the processing because the power needed is smaller and the coagulation tank can hold the volume for a long time [10]. For parameter G the greater the G value the better the performance of coagulation in homogenizing the coagulant with processing water. From the data obtained the greatest value is found in Jaluko IPAM and Gunung Putri IPAM, but from the water quality at the end of Gunung Putri IPAM processing which has better water quality than Jaluko IPAM, and Gunung Putri IPAM uses Aluminum sulfate coagulant so that it can be used as a reference coagulation and performance of the coagulant in water treatment. So, the parameter G that will be used as the design criterion is the value of Gunung Putri IPAM of 822/second. For the Gtd value that will be used as the design criteria is the Gunung Putri IPAM value of 6575 because it is in the data range and has good production water quality.

In this research also doing jar test to determine the optimum dose of coagulant to be used. The choice of coagulant type is adjusted to the type of colloid contained in water. The level of ease of destabilization of colloidal particles is influenced by the potential zeta price that allows the attraction of attraction between colloidal particles to form floc. [21] In the planning of the coagulant IPAM Klapanunggal to be used, namely, 1% Aluminum sulfate coagulant. With the measurement of the initial turbidity in the Cileunghesi river, raw water of 36.85 NTU and the Aluminum sulphate coagulant dose used in theartart experiment was 0-50 ppm (Fig. 1).

![Fig. 2. Result of Jartest with dose 25-30 ppm](image)

**TABLE 4**

<table>
<thead>
<tr>
<th>No.</th>
<th>Data</th>
<th>Type</th>
<th>Debit (L/sec)</th>
<th>Design Criteria G (sec)</th>
<th>Gtd (sec)</th>
<th>Gd (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Gsasim [18]</td>
<td>Hidrolis</td>
<td>10-300</td>
<td>100-1000</td>
<td>30.000</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Reynold [19]</td>
<td>Hidrolis</td>
<td>&lt;60</td>
<td>-</td>
<td>60.000</td>
<td>-</td>
</tr>
<tr>
<td>4.</td>
<td>Tri Joko [11]</td>
<td>Hidrolis</td>
<td>60-100</td>
<td>50-1000</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>IPAM Sengkung [10]</td>
<td>Hidrolis</td>
<td>10</td>
<td>500-1000</td>
<td>13743</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>IPAM Rawa Lumbi [9]</td>
<td>Hidrolis</td>
<td>50</td>
<td>500-1000</td>
<td>26237</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>IPAM Toriya [20]</td>
<td>Hidrolis</td>
<td>50</td>
<td>500-1000</td>
<td>16928</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>IPAM Citayam Instalasi Kedashi [8]</td>
<td>Hidrolis</td>
<td>50</td>
<td>500-1000</td>
<td>10436</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>IPAM Teluk Buyung [17]</td>
<td>Hidrolis</td>
<td>50</td>
<td>500-1000</td>
<td>31993</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>IPAM Gunung putri</td>
<td>Hidrolis</td>
<td>50</td>
<td>500-1000</td>
<td>6575</td>
<td></td>
</tr>
</tbody>
</table>

In the experiment Fig.1, data on the decrease in turbidity values below 5 NTU were found in the range of 25-30 ppm. The French test was carried out again using doses of 25-30 ppm to obtain the most optimum dose (Fig. 2). On the graph of the results of the jartest (Fig. 2) there was a data reduction in turbidity values below 5 NTU at a dose of 28 ppm, so it could be concluded that the optimum dose of Aluminum sulfate coagulant was 28 ppm. This coagulant measurement has a value that falls into the range of the optimum coagulant dose value of Aluminum sulfate in Gunung Putri IPAM as a reference IPAM, which is 24 ppm-36.5 ppm.

![Fig. 1. Result of Jartest with dose 0-50 ppm](image)
From the results of the experiment, the greater the coagulant dose, the smaller the turbidity value, because in general the aluminum sulfate coagulant dose will increase along with increasing turbidity, but this does increase is not directly proportional to the increase in turbidity. [22] Aluminum sulfate promotes the operation of the sweep coagulation mechanism in precipitates. This mechanism results in large, easy to settle floc, thus providing a decrease in turbidity with higher efficiency compared to the charge neutralization mechanism. The mechanism that works in this situation is charge neutralization, where positively charged precipitates will be adsorbed to the particle surface, followed by reducing repulsive forces that can trigger coagulation. [23]

3.2.2 Flocculation
In the designing of Klapanunggal IPAM, the type of flocculation that will be used is hydraulic flocculation with a number of six compartments. Flocculation is a water treatment unit using slow stirring that considers the speed to prevent floc rupture due to excessive pressure, so it must consider the difference in water levels that exist in each compartment. This slow stirring aims to produce large floc particles that easily settle quickly. Analysis of the comparison of design criteria parameters can be seen in Table 5. From the analysis of the flocculation unit, the detention time (td) parameters in the flocculation unit may not have values that are too large or too small, because if the value of td on the flocculation unit is too large there will be precipitation of the formed floc, and if the td value is too small causing floc to not form optimally. The td value that will be used is the value of Sungai Sengkuang IPAM which is equal to 18 minutes, because it has the smallest value of all data even though it is not included in the existing range but the final water quality results from the processing are good. The inclusion of the Gunung Putri IPAM value into the range due to differences in water sources used in each data. In the flocculation unit, there is a combination of core floc so that the value of G in the flocculation unit is expected to decrease in each of its compartments so that the floc formed does not break [1]. For the G parameter, a decrease in each compartment is Sungai Sengkuang IPAM with a value range of 46-25 / s and Kedunguling IPAM with a value range of 54-22 / s. Based on the results of the quality of production water, IPAM Kedunguling has better production water quality than Sungai Sengkuang IPAM. So, for the parameter G the value used is Kedunguling IPAM with a value range of 54-22 / second. The Gtd value is 39,000 from the multiplication of td Kawamura value of 30 minutes and the G value of IPAM Kedunguling is 22 / sec which meets the range of the Gtd value of IPAM Kedunguling.

3.2.3 Sedimentation
In the designing of IPAM Klapanunggal, the type of sedimentation used is a sedimentation plate settler with an upflows flow with a square-shaped building. Analysis of the comparison of design criteria can be seen in Table 6. In the sedimentation unit, there is the deposition of the formed floc, the td parameter affects the amount of floc particle deposition. So the longer the detention time, the higher the deposition efficiency. The highest td value is the Jaluko IPAM value of 94 minutes and the Rawa Lumbu IPAM with a discharge of 68 L/sec at 78 minutes. Judging from the production water quality data, IPAM Rawa Lumbu has better production water quality than Jaluko IPAM, so that what will be used as the design criteria is the value of Rawa Lumbu IPAM with 68 L/sec discharge of 78 minutes. So values or sedimentation surface loads greatly affect the efficiency of removing particles from water, the greater the value So the better the sedimentation efficiency in removing particles from water [10]. The highest

### Table 5: Comparison Data of Design Criteria Flocculation

<table>
<thead>
<tr>
<th>No.</th>
<th>Data</th>
<th>Tipe</th>
<th>td (minute)</th>
<th>K 1</th>
<th>K 2</th>
<th>K 3</th>
<th>K 4</th>
<th>K 5</th>
<th>K 6</th>
<th>Total</th>
<th>Gtd</th>
<th>K 1</th>
<th>K 2</th>
<th>K 3</th>
<th>K 4</th>
<th>K 5</th>
<th>K 6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kawamura</td>
<td>Hydrolik</td>
<td>43.6</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>218</td>
<td>46-25</td>
<td>1200</td>
<td>1200</td>
<td>9295</td>
<td>6324</td>
<td>6324</td>
<td>4381</td>
<td>5033</td>
</tr>
<tr>
<td>2</td>
<td>Qasim</td>
<td>Hydrolik</td>
<td>2.93</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>54-22</td>
<td>22986</td>
<td>5746</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reynold</td>
<td>Hydrolik</td>
<td>7.5</td>
<td>16</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>105-111</td>
<td>545</td>
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<td>579</td>
<td>8</td>
<td></td>
<td></td>
<td>1697</td>
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<td>4</td>
<td>Tri Joko</td>
<td>Hydrolik</td>
<td>2.52</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10-9</td>
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<td>1560</td>
<td>1540</td>
<td>1510</td>
<td>1368</td>
<td>9118</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Doroste</td>
<td>Hydrolik</td>
<td>2.63</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>344-150</td>
<td>4542</td>
<td>3634</td>
<td>3634</td>
<td>2725</td>
<td></td>
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<td>1453</td>
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<td>6</td>
<td>IPAM Sengkuang</td>
<td>Hydrolik kompartemen</td>
<td>1.78</td>
<td>11</td>
<td></td>
<td></td>
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<td></td>
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<td>17</td>
<td>1819</td>
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<td>7</td>
<td>IPAM Kedunguling</td>
<td>Hydrolik kompartemen</td>
<td>3.10</td>
<td>12</td>
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<td></td>
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<td>8</td>
<td>IPAM Jaluko</td>
<td>Hydrolik</td>
<td>2.48</td>
<td>11</td>
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<td>305-188</td>
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<tr>
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<td>IPAM Rawa Lumbu</td>
<td>Hydrolik kompartemen</td>
<td>2.46</td>
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<td></td>
<td></td>
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<td>7</td>
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<tr>
<td>10</td>
<td>IPAM Prapatan</td>
<td>Mekanis blade kompartemen</td>
<td>2.51</td>
<td>9,5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>48-38</td>
<td>7216</td>
<td>7922</td>
<td>6209</td>
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<tr>
<td>11</td>
<td>IPAM Citayam</td>
<td>Instalasi Kedashih</td>
<td>2.25</td>
<td>64-37.5</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>30-45</td>
<td>50-10</td>
<td>30,000-60,000</td>
<td>104-105</td>
<td>10,000-100,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
So value that will be used as a design criterion is the value of a laminar flow of water to prevent precipitation [14]. The Nre and NFr values that will be used as the design criteria are the Gunung Putri IPAM value with a Nre value of 12.7 and the NFr value of $1.06 \times 10^4$ because it is included in the data range and has good production water quality.

### 3.3 Water Quality Analysis of IPAM Production

This water quality analysis is obtained from secondary data regarding the quality of production water from physical, chemical and biological parameters, from each IPAM that determines whether the collection unit is running well, the water quality data of production can be seen in Table 7. From the results of the analysis of water quality in several IPAM's, it is known that the Sungai Sengkuang IPAM has a DO value and its pH does not meet the quality of drinking water according to Minister of Health Regulation 492 of 2010 and IPAM Prapatan has Ammonia values still exceeding water quality standards according to Minister of Health Regulation 492 of 2010.

### 5 CONCLUSION

Conclusions from the results of comparative analysis of literature studies and the results of the Gunung Putri IPAM evaluation on coagulation, flocculation and sedimentation units and production water quality, indicated that the design criteria to be used at IPAM Klapanunggal is as follow: the coagulation unit used the detention time (td) 8 seconds, the G value used is 822/sec, and for the Gtd value to be used is 6575. In the flocculation unit, the value of td used is equal to 18 minutes, for G value used is the range from 54 to 22/sec, and for the value of Gtd used 39.000. In the sedimentation unit, the td value used is 78 minutes, and for the Surface loading value is 5.8 $m^3/m^2/hour$, the Reynolds Number (NRe) is 12.7, and the Freud Number (NFr) is $1.06 \times 10^4$.

### REFERENCES


