The Effect of Filter Media Grain Size on the Headloss and Backwash Duration at PT PAM Lyonnaise Jaya (PALYJA)

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Abstract
Penelitian ini membahas pengaruh ukuran butiran media filter terhadap kehilangan tekanan (headloss) dan durasi pencucian balik (backwash) pada unit saringan pasir cepat. Tujuan dari penelitian ini adalah untuk menganalisis pengaruh ukuran butiran media filter terhadap headloss dan durasi backwash. Dalam penelitian ini, digunakan media filter dengan 3 ukuran berbeda yang dinilai berdasarkan parameter ukuran efektif (ES) dan koefisien keseragaman (UC). Pengumpulan data terdiri dari analisis saringan media filter, uji headloss, uji kekeruhan, dan uji TSS. Uji Headloss dilakukan pada skala laboratorium menggunakan prototipe unit filter. Analisis saringan media filter, uji kekeruhan, dan uji TSS pada air backwash dilakukan di IPA 2 PT PAM Lyonnaise Jaya. Hasil penelitian menunjukkan bahwa setiap nilai headloss untuk media filter besar (ES = 1,29 mm; UC = 1,40), media filter kecil (ES = 0,87 mm; UC = 1,51), dan media filter campuran (ES = 0,89 mm; UC = 1,49) masing-masing adalah 4 cm, 5,5 cm, dan 4,6 cm. Durasi backwash optimal pada media filter besar, media filter kecil, dan media filter campuran adalah 15 menit, 13 menit, dan 14 menit.

Keywords: durasi backwash, ukuran efektif, media filter, headloss, koefisien keseragaman

Abstract
This research is about the effect of filter media grain size on the headloss and backwash duration of rapid sand filter unit. The purpose of this study is to analyze the effect of filter media grain size on headloss and backwash duration. In this research, filter media with 3 different sizes are used, which are assessed based on the effective size (ES) and uniformity coefficient (UC) parameters. Data collection consists of sieve analysis of media filter, headloss test, turbidity test, and TSS test. The Headloss test is carried out on a laboratory scale using a prototype filter unit. Sieve analysis of media filter, turbidity test, and TSS test of backwash water are carried out at IPA 2 PT PAM Lyonnaise Jaya. The results show that each value of headloss for large filter media (ES = 1.29 mm; UC = 1.40), small filter media (ES = 0.87 mm; UC = 1.51), and mixed filter media (ES = 0.89 mm; UC = 1.49) are 4 cm, 5.5 cm, and 4.6 cm. The optimum backwash duration on large filter media, small filter media, and mixed filter media are 15 minutes, 13 minutes, and 14 minutes.

Keywords: backwash duration, effective size, filter media, headloss, uniformity coefficient

Introduction
The needs of clean water in DKI Jakarta reaches 1,2 billion m^3 and only 36% is met by PAM (Lie, 2015). The use of groundwater in DKI Jakarta reaches 62% compared to other sources, but 93% of groundwater in DKI Jakarta is already polluted (Lie, 2015). Therefore, PT PAM Lyonnaise Jaya (PT PALYJA) wants to increase the production capacity in 2019 so that it can meet the needs of clean water in DKI Jakarta. PT PALYJA's raw water sources are Jatiluhur Reservoir, Krukut River and Cengkareng Drain (Warsilah, 2019). To increase the production capacity, PT PALYJA needs to ensure and prepare its processing units, one of which is the filtration unit as the final unit which ensures that the processed water has a turbidity level below the quality standard (Hakim L, 2011; Vembrio et al., 2023). The filtration unit at PT PALYJA does not meet the standard filter media depth with an average filter media depth of 82 cm, while the standard value is 90-110 cm (Qasim et al., 2000). The deeper the filter, the greater amount of filter media so that the removal of pollutants will run more effectively (Davis ML, 2010).
Each filtration unit operating at PT PALYJA's Water Treatment Plant (IPA) 2 gets a flow supply of 0.103 m^3/s so that the filtration speed of each unit is 5.17 m/s. The higher of the discharge will increase the value of the filtration rate and increase the value of head loss and the removal of turbidity in the filter media. This will cause clogging so that the filtration unit is more often backwashed (Davis ML, 2010). The larger size of the filter media will increase the porosity value of the filter media (Maryani et al., 2014). The greater the porosity value, the lower of head loss (Davis ML, 2010). Thus, the grain size of the filter media is a very important factor to determine the performance of the filtration unit. The most representative filter media size parameters are effective size (affecting removal efficiency) and uniformity coefficient (affecting porosity values) (Hakim L, 2011). This indicates that it is necessary

to select the grain size of the filter media in the filtration unit at PT PALYJA. The selection can be made with three variations of filter media sizes, it is with large, small, and mixed size variations (50% large size and 50% small size).

Maintenance of the filtration unit aims to ensure that the filter media can work properly and can be done by the backwashing as an efforts to wash the filter media by paying attention to the duration of the backwash (Mines, 2014). If the backwash duration is too short, the sludge left in the filtration unit cannot be removed properly (Mines, 2014). Meanwhile, if the backwash duration is too long, the cost of electricity usage and the amount of water usage will increase. Therefore, this study aims to analyze the effect of filter media grain size on pressure loss and removal efficiency, backwash duration, sludge accumulation profile before and after backwash, and sludge removal during backwash.

Methods

Data Collection

The data used in this study were obtained from testing of three filtration units at PT PALYJA IPA 2 DKI Jakarta. The three filtration units include a filter unit with existing filter media, larger than the existing one, and a mixture of both. The tests consist of sand analysis, turbidity and TSS tests, as well as pressure loss tests. The pressure loss test consists of a piezometric experiment and a turbidity test on the filter prototype outlet.

Data Analysis

Data analysis was performed using Microsoft Excel software to process data and create graphs. The use of Microsoft Excel is useful to simplify the analysis process. Then the data that has been obtained is processed into a report using Microsoft Word.

Result and Discussion

Filter Media Characteristics

Factors that influence operational and backwash performance in this study are the characteristics of the three existing filter media variations. This characteristic is indicated by the effective size (ES) and the uniformity coefficient (UC). The effective size is a measure of the diameter in percentiles 10 ($ES = d_{10}$) that is able to hold 90% of the filter media weight fraction. The UC is a number that shows the ratio between the diameter at percentiles 60 and the diameter at the percentiles 10 ($UC = d_{60}/d_{10}$). The smaller of the UC value, the more uniform of the size of the filter media will be. If the filter media is more uniform, the filter media will be more easy to clogging (Mines, 2014).

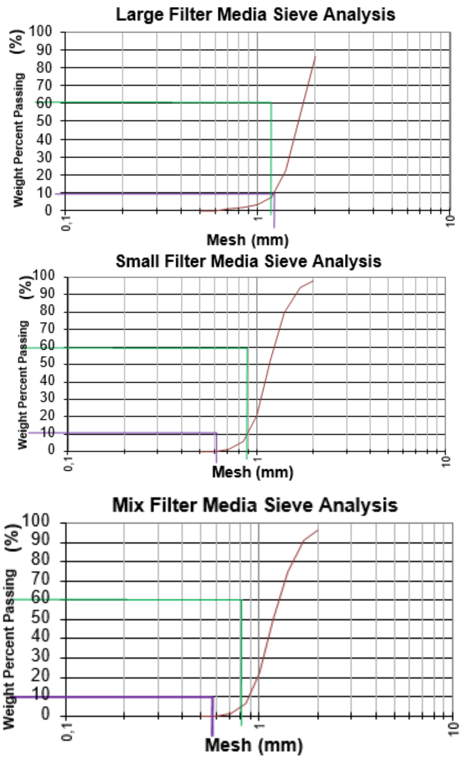

Fig. 1. Sieve analysis graphs for each filter media.

Figure 1 shows a graph of the sieve analysis for each variation of filter media. ES and UC values are obtained by finding the percentage value of the weight that passes, then a graph is made with the diameter of the sieve hole as the x value and the percentage of weight that passes as the y value. Straight lines y = 10% and y = 60% are drawn until they reach the lines that are the percentage of weight that passes to find the values of d_{10} and d_{60}. ES and UC values are calculated in the following steps:

(Example of calculation of ES and UC of mixed filter media)

$$ES = d_{10} \quad (1)$$

$$ES = 0.89$$

$$UC = \frac{d_{60}}{d_{10}} \quad (2)$$

$$UC = \frac{1.33\ mm}{0.89\ mm}$$

UC=1.49

Table 1. The different characteristics of each filter media specification

Size Variations	*Effective Size* (ES)	*Uniformity Coefficient* (UC)
Large	1.25 mm	1.40

Table 1 shows the ES and UC values of each filter media based on the calculations that have been done. By calculating the ES and UC values, the ES and UC values for large, small, and mixed filter media are 1.25 mm and 1.40; 0.87 mm and 1.51; as well as 0.89 and 1.49. The order of ES values from largest to smallest is large filter media, mixed size filter media, and small filter media. This is in accordance with each filter media size. Large filter media will tend to have a large composition of media grains so that the ES value will be even greater. Small size filter media tends to have a small composition of media grains so that the ES value will be smaller (Davis ML, 2010). The mixed filter media has an ES size larger than the small filter media and smaller than the grain size of the large filter media because this filter media is a mixture of large and small filter media.

The ES value will affect the pressure loss and sludge accumulation profile of the filter media. The greater of the ES value, the more effective the pollutant removal will be (Davis ML, 2010). As a result, the amount of pollutants retained in the filter media will be greater and cause the amount of sludge left on the filter media to increase. The UC value affects the pressure loss value, backwash duration, and the efficiency of the backwash removal. The greater the UC value, the faster the filter media will become clogged, causing the loss value to increase faster. The increase in loss value is shown visually by the increase in water level. In addition, if the UC value and porosity are larger, the media expansion height during backwashing will be smaller so that the backwash duration will be longer and the removal efficiency will be lower (Hakim L, 2011).

Effect of Filter Media Variations on Head Loss

The passage of the filtration process results in an increase in the value of the pressure loss over time. The increase in the value of the pressure loss is due to the compression (clogging) that occurs because the volume of empty space between the grains of the filter media will be less.

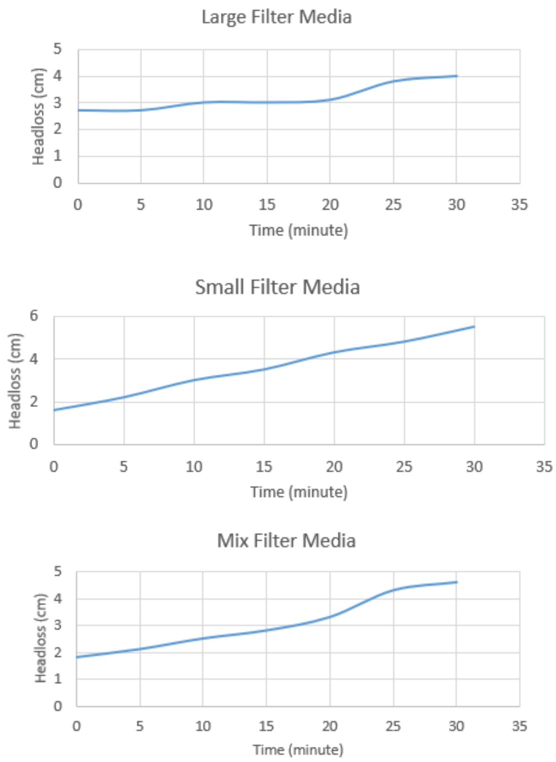

Fig. 2. Graphs of headloss with time for each filter media.

Figure 2 shows the graph of the change in pressure loss value over time. The graph proves that as the removal process progresses, the value of the pressure loss will continue to increase due to reduced volume of the empty space between the filter media grains. The decrease in the volume of the empty space between the media grains is shown by the decrease in the turbidity level. The volume of empty space will continue to be filled with pollutants that are carried along with the water so that the turbidity level of the water decreases.

Table 2. Comparison of the value of the pressure loss against the variation of filter media

Filter Media Variations	Head Loss Value	ES	UC	Average Allowance Efficiency

Large	4 cm	1.25 mm	1.40	70.39%
Small	5.5 cm	0.87 mm	1.51	77.19%
Mixture	4.6 cm	0.89 mm	1.49	71.78%

Based on Table 2, the order of head loss values from smallest to largest is large filter media, mixed filter media, and small filter media. The sequence is following the theory. The larger size of the filter media, the smaller of the head loss. The size of the filter media is represented by the ES and UC values. A large ES value will lead to more effective pollutant removal so that more pollutants are kept in the filter media. This is showed by the average removal efficiency. Large filter media has a removal efficiency of 70.39%. Mixed filter media has a removal efficiency of 71.78%. Small filter media has the best removal efficiency of 77.19%. If there are more pollutants, the filter media will experience clogging and cause the pressure loss value to increase. For the UC parameter, the smaller the UC value, the more uniform the grain size of the filter media will be. If the grain size of the filter media is more uniform, the filter media will not easily experience clogging and result in an increase in the pressure loss value.

Effect of Filter Media Size on Backwash Duration
The TSS measurement is the basis for finding the duration of the backwash, especially in the rinsing stage where the washing water begins to fall towards the washing water disposal canal. The washing duration is figured out based on the measured TSS value, if the TSS value is ≤ 1 mg/l then the backwash process can be stopped. The turbidity value measurement aims to find the benchmark for changes in TSS values. If the TSS value decreases, the turbidity value also decreases and vice versa.

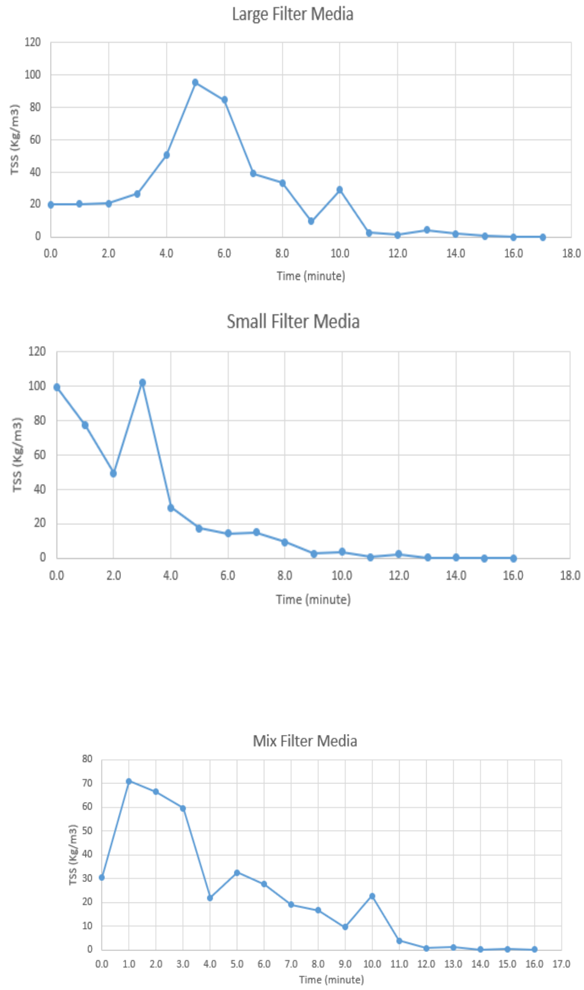

Fig. 3. Graphs of change in TSS value against time

Based on Figure 3, another thing that can analyzed is the duration to reach the maximum allowance during the backwash process. In the graph, the duration for large filter media to reach the maximum removal is 1 minute. The factor that affects the duration of this maximum removal is the porosity of the filter media. Based on the backwash hydraulics formula, the greater the porosity value, the lower the height of the media that can expanded during backwashing. Porosity related to UC parameter. The more uniform the filter media, the smaller the volume of empty space between the filter media grains (porosity). The uniformity of the filter media is showed by the UC value. The higher the UC value, the more non-uniform the filter media will be. Therefore, in deciding the duration of removal, porosity can be represented by the UC parameter. Large filter media has a UC value of 1.49. With such a UC value, the height of the expanded media to be lower and the maximum removal duration will be slightly longer.

The large filter media was backwashed for 16 minutes. However, based on the graph at 14−16 minutes, the TSS value was less than 1 mg/liter. This shows that the backwash duration should shortened to 14 minutes. When compared with theory, this backwash duration meets the standards. A suitable backwash duration is 10−20 minutes.

Table 3. Comparison of the duration of backwash and the duration of achieving the maximum allowance for backwash

Filter Media Variations	Backwash duration (minutes)	Maximum Allowance Duration (minutes)	ES	UC
Large	15	5	1.25 mm	1.40

Based on Table 3, the order of backwash duration from shortest is small filter media, mixed filter media, and large filter media. This is following the order of the size of the filter media from smallest to largest. The size of the filter media is represented by the ES and UC parameters. The filter media that has the smallest size will have the shortest backwash duration value because the small size filter media has a lighter weight. If the filter media has a lighter weight, the filter media will be lifted more easily so that the sludge removal in the filter media can take place more quickly. Thus, the large filter media has the longest backwash duration and the small filter media has the shortest backwash duration.

On mixed filter media, the duration to reach the maximum removal is only 1 minute. The factor that causes this is the sludge accumulation profile of the mixed filter media before backwash which is the lowest among other filter media. The range of mixed filter media turbidity values is the smallest. Meanwhile, filter units with large and small filter media have a maximum removal duration of 5 and 3 minutes. This is by the backwash hydraulics formula. Large filter media has the largest UC value. The larger the UC value, the smaller the porosity. This smaller porosity causes the expansion height of the filter media during backwash to be smaller so that it takes the longest time to reach the maximum removal. Following the theory, the opposite also occurs in small filter media.

Conclusion

The grain size of the filter media has an effect on the pressure loss and removal efficiency. The value of the pressure loss and the highest removal efficiency is in the small filter media (ES = 0.87 mm and UC = 1.51) which is 5.5 cm with an average removal efficiency of 77.19%. The value of pressure loss and the lowest removal efficiency is in the large filter media (ES = 1.25 mm and UC = 1.40) which is 4 cm with an average removal efficiency of 70.39%. The value of pressure loss and removal efficiency for mixed filter media (ES = 0.89 mm and UC = 1.49) is 4.6 cm with an average removal efficiency of 71.78%. The larger the size of the filter media, in this case represented by ES, the lower the pressure loss and removal efficiency and vice versa.

The grain size of the filter media affects the backwash duration and the maximum removal duration when backwashed. The backwash duration and the maximum removal duration on small filter media are 13 minutes and 3 minutes. Backwash duration and maximum removal duration on mixed size filter media were 14 minutes and 1 minute. Backwash duration and maximum removal duration on large filter media are 15 minutes and 5 minutes.

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