Journal of Sustainable Infrastructure

Turbidity Reduction by Using Variations of Filtration Media Sizes (Case Study of Treated Water PT. X Jakarta)

Leonardus Alvin Widi Vembrio[1], Nurulbaiti Listyendah Zahra[1], Ariyanti Sarwono[1], Natasya Hikmat Putri[1], Rofiah[1]

[1]Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Komplek Universitas Pertamina, Jakarta, Jakarta Selatan, Indonesia

*Correspondence: nurulbaiti.lz@universitaspertamina.ac.id

Diterima : 11 Juni 2023 Disetujui: 23 Oktober 2023

Abstrak

Kekeruhan merupakan salah satu parameter kualitas air utama dalam kualitas air minum. Salah satu cara menurunkan kadar kekeruhan adalah dengan cara filtrasi. Unit filtrasi dalam water treatment plan harus menggunakan media yang sesuai agar air baku hasil olahan memenuhi standard World Health Organization (WHO). WHO menyebutkan kekeruhan air hasil olahan sebelum didesinfeksi adalah 1 NTU. Penelitian ini dilakukan dengan tujuan mengetahui efisiensi pengolahan filtrasi dengan berbagai media dalam menurunkan konsentrasi kekeruhan dalam air baku. Penelitian ini menggunakan tiga jenis media yaitu 50% pasir silika ukuran mesh 12-16 dan 50% pasir silika ukuran mesh 8-12 (C), 100% pasir silika ukuran mesh 12-16 (K), dan 100% pasir silika ukuran mesh 8-12 (B). Nilai Porositas untuk masing-masing sampel C, K, dan B adalah 0,412; 0,423; dan 0,388. Waktu detensi saat debit maksimum untuk sampel C, K, dan B masing-masing adalah 3,6; 3,76; dan 3,45 menit. Flow rate yang digunakan untuk masing-masing sampel media C, K, dan B adalah 4125 L/s dan 2500 L/s. Efisiensi penyisihan yang dihasilkan kekeruhan paling tinggi didapatkan pada media C dengan nilai 90,8% dan 89,9%. Sedangkan media B memberikan efisiensi penyisihan kekeruhan paling rendah yaitu 86,3% dan 86,4%. Hasil seluruh variasi media yang digunakan telah memenuhi standard WHO dimana hasil olahan sudah menghasilkan konsentrasi kekeruhan 0,25 - 0,32 NTU.

Keywords: kekeruhan, media, filtrasi, baku mutu

Abstract

Turbidity is one of the main water quality parameters in drinking water quality. One way to reduce turbidity levels is by filtration. The filtration unit in the water treatment plant must use appropriate media so that the processed raw water meets World Health Organization (WHO) standards. WHO states that the turbidity of processed water before disinfection is 1 NTU. This research was conducted to know the efficiency of filtration processing with various media in reducing the concentration of turbidity in raw water. This study used three types of media, namely 50% silica sand with a mesh size of 12-16 and 50% silica sand with a mesh size of 8-12 (C), 100% silica sand with a mesh size of 12-16 (K), and 100% silica sand in mesh size. 8-12 (B). Porosity value for each sample C, K, and B is 0.412; 0.423; and 0.388. The detention time at maximum discharge for samples C, K, and B was 3.6, respectively; 3.76; and 3.45 minutes. The flow rates used for media samples C, K, and B were 4125 L/s and 2500 L/s, respectively. The removal efficiency produced by the highest turbidity was obtained in medium C with values of 90.8% and 89.9%, respectively. Meanwhile, media B gave the lowest turbidity removal efficiency, namely 86.3% and 86.4%. The results of all variations of the media used have met WHO standards, where the processed results have produced turbidity concentrations of 0.25 - 0.32 NTU.

Keywords: turbidity, media, filtration, standard

Introduction

Based on its population, Jakarta can be categorized as a metropolitan city that must have a supply of clean water and drinking water in more than 80-240 L/household.Day (Budirahardjo & Tandi, 2020). The water treatment plant (WTP) must be designed to continue to produce water that is suitable for consumption by the community continuously regardless of the weather and environmental conditions. The decrease in the quantity and quality of surface water in the city of Jakarta also causes the need for a change to the existing design (Fadhilah et al., 2020; Sofiyah et al., 2021; Hasnaningrum et al., 2021, Khansa et al., 2020) to produce air that is consumed continuously. The systems and subsystems in the installation to be designed must be simple, effective, reliable, durable and inexpensive in financing (Balitbang, 2013).

In its application, one of the units that play an essential role in water treatment is PT. X is the filtration unit. The main water quality parameters that determine the performance of drinking water treatment systems are the concentration of suspended solids contained; this is due to changes in the composition and concentration of suspended solids that fluctuate. In addition, suspended solids generally act as the primary transport mechanism for organisms and emerging pollutants (Packman et al., 1999; Tiveron et al., 2018). Turbidity is one of the parameters used to indirectly describe the concentration of suspended solids, which can be measured easily due to the strong relationship between the two parameters (Daphne et al., 2011; Villa et al., 2019). The suspended solids analysis is relatively long compared to turbidity analysis (Susfalk et al., 2008). The removal of turbidity is essential because, in clean water or drinking water, the turbidity parameters have been regulated and standardized by the Ministry of the Health Republic of Indonesia, including 0.5 NTU for turbidity in clean water, and the WHO standard is 1 NTU before the indexing process.

Existing condition PT. X used a rapid sand filter filtration unit process. The filtration unit is a device for separating solids from a fluid. This solid will later be calculated as the value of turbidity in a liquid. In principle, the filtration process occurs due to the solids in a fluid being filtered in a filtration medium used. In its application, PT. X uses a filtration unit with silica sand media in one of its processing configurations. However, the existing filtration unit of PT. X has an uneven layer of media depth, and a decrease in the effectiveness of the removal of turbidity can occur until it exceeds the quality standard. This research aimed to determine the composition of the best filtration media in reducing turbidity based on laboratory-scale experiments.

METHOD

The data used in this study is primary data. The primary data itself will be divided into 2 (two), namely field data (on-site) and laboratory-scale reactors (Figure 1) on a laboratory scale. The field data used consisted of sand filter media characterization, turbidity allowance value, headloss value based on calculation and discharge value. Meanwhile, the prototype data is used to find the headloss value to validate the existing calculation data obtained.

Figure 1. Laboratory Scale Filtration Reactor for Treating Raw Water PT. X

In this study, two analyzes of the data obtained will be carried out, namely the analysis of the effect of differences in the physical characteristics of grains of sand and discharge media on the effectiveness of turbidity removal. This research uses a turbidity meter with a working principle based on the principle of light scattering. The reference used in the measurement of turbidity is SNI 06-6989.25-2005. The variation of the filtration unit sand media based on the size distribution of the media expressed using the mesh number with the conversion value can be seen in Table 1.

Table 1. Variation of Sand Media Used

Media	Variation
C	50% of existing silica sand with a mesh size of 12-16 and 50% new condition silica sand with a mesh size of 8-12.
B	100% existing silica sand mesh size 12-16.
K	100% silica sand new condition mesh size 8-12.

Each of the existing filter sand media has been conditioned to be at the height of 100 cm and the same water inlet route to minimize significant quality differences. The sand media characterization data used include the value of effective size (ES), coefficient of uniformity (UC), the percentage of each mesh size using the sieve analysis method. The method used for sieve analysis in this study is as follows (SNI 3423: 2008). Then, to collect porosity and density data, laboratory tests will be used. After obtaining the value of the weight fraction in each sample, calculate the percentage of the weight of the retained sample and the percentage of unretained weight using equation 1 and equation 2. The method used to collect data on porosity and density in this research is SNI 2435:2008 to measure porosity and SNI 1964:2008 to measure density.

% retained = (weight per mesh (grams))/(total sample weight (grams)) x 100% (1)

% unhold = 100% - % hold (2)

Determination of the discharge value is based on observations on daily discharge patterns and is carried out for five working days. This discharge pattern comes from a digital discharge sensor from the PT X inlet, which will then be automatically converted into graphs and tables. The debit value used is the daily maximum discharge value and the daily minimum flow rate value.

Turbidity data will be the turbidity value of the water sample at the filter inlet and filter outlet. The time interval or detention time for water sampling from the inlet to the outlet will use a calculation based on the filtration speed and media depth. The calculation will use for the determination of detention time follow equation 3. After sampling, turbidity data will be obtained using a turbidimeter at a time variation that will be determined based on variations in filtration speed due to previous discharge variations.

td = layer depth/filtration rate (3)

RESULT AND DISCUSSION

Existing Condition

Existing filtration unit at PT. X has a base area of 72 $m^{2,}$ and a height of 1.4 m, and the number of units used is 34 units, and for now, the filtration process used has a downflow pattern from the filter inlet to the filter outlet. Installation of PT. X can treat as much as 2500 L/d of raw water to 4125 L/d. Existing daily debit fluctuation at PT. X can be seen in Figure 2. It can be seen that from 05.00 WIB to 20.00 WIB there was an increase in the discharge from the average daily release of raw water. This means that the filter will bear a discharge load above the average daily release for 15 hours. The existing filtration unit has a problem where the depth layer of the filtration media is uneven. It can reduce the quality of filtered water and may interfere with processing in the next unit.

Determination of Filtration Media

The selection of the characteristics of the filtration media is based on the section that PT X itself has made by considering many internal aspects. The characteristics of the media used are silica sand which has a depth of 90 cm and a density of 2.5 grams/cm^3 but has a difference in the size distribution (mesh or diameter) of grains from the existing sand media. Variations in the size of the media used are based on differences in grain diameter size distribution (which are expressed in mesh numbers). Differences in grain diameter size distribution will cause differences in the porosity value and the calculation of the headloss value. The size of the grains of sand used affects the absorption of water; the smaller the size of the sand, the aggregate structure or mineral groups will be denser so that the filter results will be better to a certain extent (Ardiatma, 2021).

Therefore, media characterization was carried out using the sieve analysis method to see further the impact of differences in the grain size distribution of the media and to find the ES and UC values from the variation in the size of the media and the laboratory test method for porosity values to look for differences in the porosity values.

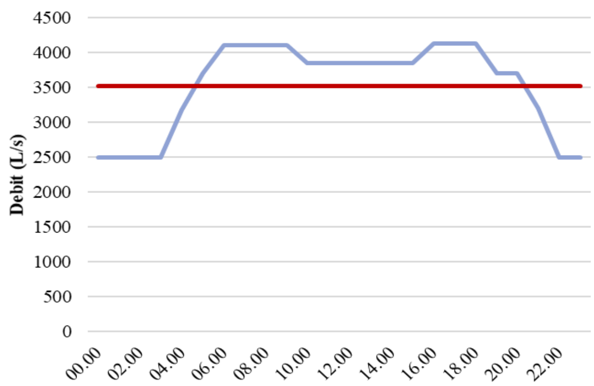

Figure 2. Daily Flow Rate Fluctuation of Raw Water to be Treated at PT X

Sample C seems to have a distribution pattern similar to Sample K but has a more negligible range difference in mesh numbers 8 and 10. All weight fractions in each sample variation are calculated by equation 3, so that the results are as shown in Table 2, Table 3, and Table 4.

Table 2 Percentage of Retained and Unretained Weight Fraction of Sample C

Dia. (mm)	No. Mesh	Retained weight (g)	% Retained	% Passing
2.38	8	11.40	3.80	96.20
2	10	15.30	5.10	91.11
1.7	12	49.30	16.42	74.68
1.4	14	72.60	24.18	50.50
1.18	16	85.00	28.31	22.19
1	18	46.80	15.59	6.60
0.85	20	15.50	5.16	1.43
0.71	25	4.30	1.43	0.00
2.38	30	0.00	0.00	0.00
TOTAL		300.20	100.00	

Table 3 Percentage of Retained and Unretained Weight Fraction of Sample B

Dia. (mm)	No. Mesh	Retained weight (g)	% Retained	% Passing
2.38	8	41.40	13.80	86.20
2	10	86.70	28.90	57.30
1.7	12	104.50	34.83	22.47
1.4	14	44.50	14.83	7.63
1.18	16	12.10	4.03	3.60
1	18	5.00	1.67	1.93
0.85	20	2.60	0.87	1.07
0.71	25	3.20	1.07	0.00
TOTAL		300.00	100.00	

Table 4 Percentage of Retained and Unretained Weight Fraction of Sample K

Dia. (mm)	No. Mesh	Retained weight (g)	% Retained	% Passing
2.38	8	6.00	2.00	98.00
2	10	11.60	3.87	94.12
1.7	12	42.90	14.32	79.80
1.4	14	82.10	27.41	52.39
1.18	16	94.80	31.65	20.73
1	18	44.50	14.86	5.88
0.85	20	13.60	4.54	1.34
0.71	25	4.00	1.34	0.00
TOTAL		299.50	100.00	

From the three variations of the media used, it can be seen that Sample K and Sample C have ES and UC values that are not much different so that they are indicated to have the same properties. In contrast to Sample B, which has relatively larger ES and UC values, it is stated that there are differences in properties. A more considerable ES value indicates a tendency to increase the porosity and then slow down the filtration speed and reduce the headloss value.

The porosity values were tested to find differences in the porosity values resulting from the previous characterization of the ES and UC values. According to Ridha & Darminto (2016), rock porosity is the ratio of the volume of the pore cavities to the total volume of all rocks expressed in per cent. The difference in the porosity value will affect the determination of the value of the filtration speed obtained. Porosity depends on the type of material, material size, pore distribution, cementation, and composition. The greater the porosity value, the faster the water will flow through the filter media (Sulianto et al., 2020). Changes in the filtration speed will also determine the headloss value to have the potential to reduce the effectiveness of the removal. The method used compares the porosity values in each media variation, and the results are shown in Table 5. From Table 5, it can be seen that the distance value is too far or significant. Sample B has the most prominent pores and is followed by Sample K. Then Sample C.

Table 5 Comparison of Porosity Values for Each Sample

Media	Porosity Value	Detention Time at Maximum Discharge (minutes)	Detention Time at Minimum Discharge (minutes)
C	0,412	3.66	6.05
B	0,423	3.76	8.05
K	0,388	3.45	5.7

Turbidity Removal

Table 6 is the average result of the number of samples in each condition. Based on the picture, it can be seen that there is a difference in the quality of the inlet filter. The units used in this study have different distances, not using the same filter unit. The difference in inlet turbidity quality is indicated to occur due to the condition of the cleanliness of the canal that connects the pulsator unit as a unit configuration before the filter unit has a difference in cleanliness over a specific distance range. Another factor that can be indicated is the researcher's human error due to the possibility of differences in sampling time when the water quality in the canal is fluctuating. The table shows the difference in quality at the inlet filter. The units used in this study have different distances, not using the same filter unit. The difference in inlet turbidity quality is indicated to occur due to the condition of the cleanliness of the canal that connects the pulsator unit as a unit configuration before the filter unit has a difference in cleanliness over a specific distance range. Another factor that can be indicated is the researcher's human error due to the possibility of differences in sampling time when the water quality in the canal is fluctuating.

The final result of the treatment shows a value of 0.25 – 0.32 NTU, this indicates that the water quality has met the standards of the Minister of Health of the Republic of Indonesia and WHO. The higher the level of turbidity, the higher the risk that people will get diseases in their digestive system, especially when the immune system decreases (Pramesti & Puspikawati, 2020). In addition, the impact of turbidity on drinking water can reduce the aesthetic value and the water treatment plan system can form deposits on the flow pipes so that the work process on the treatment system will be disturbed (Pramesti & Puspikawati, 2020).

Table 6 showed differences in the performance of the filtration media in terms of the percentage of removal. The removal efficiency of allowance will be calculated based on the range of difference between the inlet and outlet. That Sample B using new sand media has the lowest removal effectiveness when compared to other media variations. However, Sample C has turbidity removal effectiveness that is not much different from Sample K. The smaller and uniform the diameter of the media, the larger the surface area, so that the removal of pollutants will be even greater (Purnomo & Widyaningrum, 2020).

In this study, turbidity removal efficiency from discharge variations was not too different for each medium. A discharge that is too large will cause the filter not to function efficiently so that the filtration process cannot occur properly due to the flow of water that is too fast in passing through the cavity between the grains of the sand media (Sasmitha, 2017). This reduces the contact time between the grain surface of the filter media and the water to be filtered. The flow velocity is too high through the voids between the grains, causing the particles that are too fine that are filtered to escape. In addition, there are movements of the media grains which cause the pores to be closed so that clogging will quickly occur. Consequently, the ongoing filtration process will be immediately stopped. Other causes can also occur because the installation of the filtration media is not very precise, so there are many gaps on the edges of the reactor, which causes water to pass through, and turbidity value becomes higher (Afifah et al., 2019).

Table 6 Comparison of Changes in Turbidity for Each Variation of Samples

	Flow Rate	Turbidity (NTU)		Efficiency
Sample	L/s	Intlet	Outlet	%
C	4125	2.71	0.25	90.8
	2500	2.67	0.27	89.9
B	4125	2.33	0.32	86.3
	2500	2.21	0.3	86.4
K	4125	2.43	0.25	89.7
	2500	2.42	0.25	89.7

CONCLUSION

Based on the results of research that has been carried out, it is known that differences in the physical characterization of grains of sand media affect the removal of turbidity. This is evidenced by Sample K having the highest average allowance of 90.295%. Then, Sample C followed with an average percentage of reduction of 89.75%. Sample B has the third rank with an average percentage of removal of 86.42%. In addition, it is known that the difference in discharge affects the removal of turbidity. However, it is not very significant; namely, 0.1% in Sample B, 1.17% in Sample K and Sample C can have similar effectiveness values for each discharge. The final processed product has met the standards of the Indonesian government and WHO regulations. The final processed product has met the standards of the Indonesian government and WHO regulations.

REFERENCE

Afifah, A. S., Prajati, G., & Suryawan, I. W. K. (2019). Penambahan Media Karbon Aktif dan Geotekstil pada Sand Filter. JTERA (Jurnal Teknologi Rekayasa), 4(2), 237-242.

Ardiatma, D. (2021). Pengaruh Diameter Media Filtrasi Zeolit Terhadap Turbidity, Total Disolved Solids Dan Total Suspended Solids Pada Reaktor Filter. Pelita Teknologi, 15(2), 95-105..

BALITBANG Kementrian Pekerjaan Umum dan Perumahan Rakyat. Pusat Penelitian dan Pengembangan Pemukiman. (2013). Pedoman Pembangunan Sarana Dan Prasarana Air Minum.

Budirahardjo, E. K. & Tandi, W (2020). Potensi Penampungan Air Hujan Di Dki Jakarta. Jurnal Sumber Daya Air, 16(2), 77-90.

Daphne, L. H. X., Utomo, H. D., & Kenneth, L. Z. H. (2011). Correlation between turbidity and total suspended solids in Singapore rivers. Journal of Water Sustainability, 1(3), 313-322.

Fadhilah, N., Vembrio, L. A. W., Safira, R. H., Amiruddin, A., Sofiyah, E. S., & Suryawan, I. W. K. (2020). Modifikasi Unit Proses dalam Peningkatan Efisiensi Penyisihan Amonium. Jurnal Sumberdaya Alam dan Lingkungan, 7(2), 1-10.

Hasnaningrum, H., Ridhosari, B., & Suryawan, I. W. K. (2021). Planning Advanced Treatment of Tap Water Consumption in Universitas Pertamina. Jurnal Teknik Kimia dan Lingkungan, 5(1), 1-11.

Khansa, P., Sofiyah, E. S., & Suryawan, I. W. K. (2020). Determination of Rain Intensity Based on Rain Characteristics Observed from Rain Observation Stations Around South Jakarta. JACEE (Journal of Advanced Civil and Environmental Engineering), 3(2), 94-103.

Packman, J., Comings, K., & Booth, D. (1999). Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands.

Pramesti, D. S., & Puspikawati, S. I. (2020). Analysis of Turbidity Test Bottled Drinking Water In Banyuwangi District. Preventif: Jurnal Kesehatan Masyarakat, 11(2), 75-85.

Purnomo, Y. S., & Widyaningrum, H. (2020). Penurunan Bod, Cod, Dan Mlss Pada Air Limbah Tahu Menggunakan Fakultatif Anaerobic Horizontal Roughing Filter. Prosiding ESEC, 1(1), 25-32.

Republik Indonesia, (2010). Peraturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/2010 tentang Persyaratan Kualitas Air Minum.

Ridha, M., & Darminto, D. (2016). Analisis Densitas, Porositas, dan Struktur Mikro Batu Apung Lombok dengan Variasi Lokasi dan Kedalaman. JFA (Jurnal Fisika dan Aplikasinya), 12(3).

Sasmitha, D. (2017). Pemanfaatan Sampah Plastik Polyethylene Terephthalate (PET) Sebagai Media Pada Unit Pre-Filter (Doctoral dissertation, Institut Teknologi Sepuluh Nopember).

Sofiyah, E. S., Septiariva, I. Y., & Suryawan, I. W. K. (2021). Domestic Wastewater Treatment Using Various Microalgae for Lipid Production. Annals of the Romanian Society for Cell Biology, 15156-15163.

Sulianto, A. A., Aji, A. D. S., & Alkahi, M. F. (2020). Rancang Bangun Unit Filtrasi Air Tanah untuk Menurunkan Kekeruhan dan Kadar Mangan dengan Aliran Upflow. Jurnal Sumberdaya Alam dan Lingkungan, 7(2), 72-80.nya), 12(3).

Susfalk, R. B., Fitzgerald, B., & Knust, A. M. (2008). Characterization of turbidity and total suspended solids in the Upper Carson River, Nevada. DHS Publication, (41242).

Tiveron, T., Gholamreza-Kashi, S., & Joksimovic, D. (2018). A USEPA SWMM integrated tool for determining the suspended solids reduction performance of bioretention cells. Journal of Water Management Modeling.

Villa, A., Fölster, J., & Kyllmar, K. (2019). Determining suspended solids and total phosphorus from turbidity: comparison of high-frequency sampling with conventional monitoring methods. Environmental monitoring and assessment, 191(10), 1-16.

WHO. Water Quality and Health - Review Of Turbidity: Information for regulators and water suppliers.