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The Effectiveness of Activated Carbon in Reducing Color and Turbidity of Drinking Water at the Tirta Kencana Regional Water Utility Water Treatment Plant, Samarinda City

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Abstract

Activated carbon is a widely used filtration medium in drinking water treatment to reduce physical parameters such as color and turbidity. This study aims to evaluate the effectiveness of activated carbon compared to silica sand in reducing the values of color and turbidity in treated water at the Water Treatment Plant (IPA) of Perumdam Tirta Kencana, Samarinda City. The methodology included collecting laboratory test data from 17 IPAs during 2023 and conducting experiments using miniature filters with activated carbon and silica sand media. The results show that activated carbon has higher effectiveness in reducing color and turbidity, with final values meeting the drinking water quality standards based on Ministry of Health Regulation No. 2 of 2023.

***Keywords**: Activated Carbon, Turbidity, Color, Drinking Water, IPA, Perumdam*

1. Introduction

The Tirta Kencana Regional Public Water Utility (Perumdam Tirta Kencana) of Samarinda City operates 17 Clean Water Treatment Plants (Instalasi Pengolahan Air/IPA) distributed across all districts of Samarinda City, each with different production capacities. The total average clean water production is 2,930 L/s, derived from a total average raw water capacity of 3,408 L/s, serving more than 180,000 household connections (SR). The raw water sources used by the IPAs are surface water, predominantly sourced from the Mahakam River, while the remainder utilizes water from the Lempake Reservoir as raw water sources (Source: Production Report of Perumdam Tirta Kencana, June 2024).

The drinking water distributed by Perumdam Tirta Kencana Samarinda City to consumers, both for domestic and non-domestic purposes, must comply with the quality standards established by the government, such as the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, concerning Amendments to Minister of Health Regulation Number 492/MENKES/PER/IV/2010 on Drinking Water Quality Requirements. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 492 of 2010 concerning "Drinking Water Quality Requirements," drinking water is defined as water that has undergone treatment processes or untreated water that meets health (Hendra and Rianti, 2024))

One of the problems frequently encountered by Perumdam Tirta Kencana is the quality of produced water in terms of physical parameters, which at times does not meet the quality standards stipulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023. These physical parameters include turbidity and color. In water treatment plants that involve multiple processing stages, it is essential to ensure that each stage functions properly to produce water of standard quality. One of the processing stages in clean water treatment is the filtration process, which employs systems ranging from simple to advanced technologies, where the system is expected to operate effectively. The primary function of filters in clean water treatment is to remove and eliminate contaminants that may affect the quality of produced water, such as capturing fine particles (sand, silt, sediment) and other impurities that can cause water to become turbid or unsafe for consumption. Consequently, the produced clean water meets the required quality standards and is safe for public health (Metcalf & Eddy, 2014).

At the filtration stage, all 17 IPAs operated by Perumdam Tirta Kencana Samarinda currently utilize silica sand exclusively as filter media. Raw water that has undergone several treatment processes up to the

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sedimentation stage, with turbidity values measured in NTU that may still be relatively high, is filtered through silica sand media to achieve turbidity levels that comply with applicable quality standards. Silica sand is capable of retaining solid particles such as mud or soil in the form of light flocs, as well as dissolved organic substances in water. This occurs due to the pore structure of silica sand, which enables the filtration of these particles, thereby improving water quality, particularly physical parameters such as turbidity and color (Yuniarti, 2021).

An alternative solution to address these issues is to modify the filter media used in drinking water treatment by replacing or combining silica sand with activated carbon. One of the commonly used technologies in water treatment is adsorption using activated carbon. Activated carbon is typically available in the form of granular or powdered materials, characterized by a highly porous structure and a very large surface area, resulting in high adsorption capacity for various types of contaminants, including organic compounds, odor, taste, and heavy metals. The use of activated carbon in drinking water treatment at Regional Drinking Water Companies (PDAM) can improve water quality in terms of physical, chemical, and organoleptic aspects (taste and odor), making the water safer and more suitable for public consumption (Rokhmat, 2020).

Activated carbon is a filtration medium widely used in drinking water treatment due to its high adsorption capacity for organic compounds, color, odor, and turbidity. The primary advantage of activated carbon lies in its large pore surface area, which makes it effective in removing both micro- and macro-contaminants such as free chlorine, pesticides, and volatile compounds (Babel & Kurniawan, 2003). In addition, activated carbon is relatively inexpensive, readily available, and can be produced from various natural materials such as coconut shells, wood, and coal (Rashed, 2013). However, the use of activated carbon also has certain limitations. One of the main challenges is the decline in adsorption capacity over time due to media saturation, which necessitates periodic regeneration or replacement (Bansal & Goyal, 2005). Furthermore, if not properly managed, activated carbon may become a medium for microbial growth due to its nutrient-adsorbing properties, potentially leading to secondary contamination of water (WHO, 2017). Therefore, the effectiveness of activated carbon in water treatment must be accompanied by strict operational control and routine maintenance to ensure that the produced water continues to meet health standards.

1. Based on the background described above, the research problems formulated in this study are as follows:
2. Does the quality of physical parameters of drinking water after filtration at the Perumdam Tirta Kencana Samarinda City IPAs, based on periodic examination results, comply with the applicable regulatory standards?
1. Is the use of activated carbon as a filter medium effective in improving physical quality parameters, particularly turbidity and color, of drinking water after the sedimentation process to produce drinking water that meets the applicable standards?

2. Methodology

The study was conducted through the collection of laboratory data from clean water samples obtained from Water Treatment Plants (IPAs). The research involved collecting sampling reports from 17 IPA units, consisting of clean water samples taken from IPA reservoirs. Sampling and laboratory analysis were carried out at the internal laboratory of Perumdam Tirta Kencana Samarinda City throughout 2023. The results of the physical parameter analyses from these locations were used as evaluation materials based on the applicable regulations, namely the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 and the Regulation of the Minister of Health of the Republic of Indonesia Number 492/MENKES of 2010 (which was still in effect in 2023 and therefore served as the basis for drinking water quality standards).

The total number of samples was calculated, and the results of the physical parameter examinations were verified and classified into two categories: meeting the standards (MS) and not meeting the standards (NMS). These results were then presented in tabular form. Based on the calculation of the number of samples and the proportion of physical parameters that met or did not meet the standards, an overview of the existing water quality conditions at several IPAs operated by Perumdam Tirta Kencana Samarinda City was obtained. Based on these existing quality conditions, the authors propose one possible effort to improve water quality at the filtration stage of the clean water treatment process (IPA).

A small-scale experimental study using sand media was conducted to evaluate the use of activated carbon as a filter medium at the micro scale during the filtration stage. The equipment and materials used included a HACH 2100N turbidimeter, HACH DR6000 spectrophotometer for color measurement, Orion Star A212 TDS meter, 1,000 mL graduated cylinder, silica sand, granular activated carbon derived from coconut shells, as well as supporting equipment for the mini filter system such as piping accessories and a dedicated filter vessel.

The experimental procedure was as follows: first, the IPA location was selected as the experimental site based on previous routine monitoring results, which indicated a higher frequency of physical parameters failing to meet the standards. Two filter units were then constructed, consisting of a silica sand filter and an activated carbon filter, respectively. Each filter unit comprised a small basin, nozzle, filter media, and piping accessories, as illustrated in the following schematic:

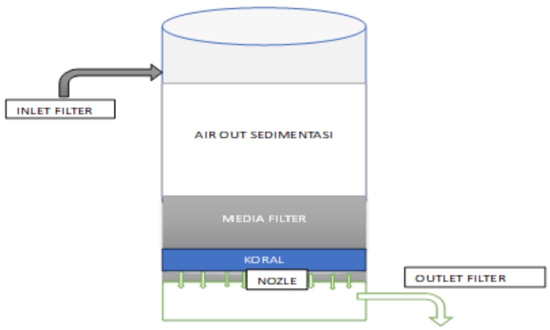

Figure 1. Measurement of the input water capacity to the filter from sedimentation was conducted volumetrically, with equal volumes of influent water supplied to each filter.

During the experiment, each filter medium was tested under three treatment conditions, with media thicknesses of 10 cm, 20 cm, and 30 cm. At each stage, water samples were collected before and after filtration. The samples were subsequently analyzed both on-site and in the laboratory. The filtration tests were conducted three times over a three-week period, at random times, at the same IPA location. Based on the experimental results from the three treatments, an effectiveness analysis was performed to evaluate the performance of both filter media in terms of reductions in color and turbidity values.

3. Result and Discussion

3.1 Existing Water Quality

The results of water quality data analysis from 17 Water Treatment Plants (IPAs) indicate that during 2023, there were still drinking water samples that did not meet the quality standards for turbidity and color parameters. Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010, approximately 26.04% of samples had turbidity values exceeding 5 NTU. Meanwhile, according to the Regulation of the Minister of Health No. 2 of 2023, which stipulates a maximum turbidity limit of 3 NTU, the percentage of non-compliant samples increased to 45.96%. For the color parameter, most samples met the quality standards; however, a small number of samples still exceeded the limit of 15 PtCo.

Based on the verification of sampling reports collected from the 17 IPAs operated by Perumdam Tirta Kencana Samarinda City, and evaluated according to Minister of Health Regulation No. 2 of 2023 and Minister of Health Regulation No. 492/MENKES of 2010 (which remained applicable in 2023 as the reference for drinking water quality standards), the following data were obtained Table 1.

Table 1. Example of Report Verification Results Based on Minister of Health Regulation No. 492 of 2010, Central Laboratory of Perumdam Tirta Kencana.

Januari 2+A99:I135023	tgl	Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	Keterangan
Parameter								
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl²	
Kadar Maksimum yang diperbolehkan		5,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA LOA BAKUNG	2							Jumlah sampel = 5
Reservoir I (Air Produksi)		2,75	46,10	64,70	0	6,80	1,0	TMS = 2
Reservoir I (Air Produksi)		3,00	54,55	76,65	17	6,86	1,4	MS = 4
Reservoir I (Air Produksi)		4,58	47,40	68,10	14	7,00	1,0	Kekeruhan = 1
Reservoir I (Air Produksi)		7,66	53,35	79,00	0	7,41	1,2	Warna = 1
Reservoir I (Air Produksi)		4,26	52,75	79,45	6	6,95	0,8	
Januari 2023	tgl	Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	Keterangan
Parameter								
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl²	
Kadar Maksimum yang diperbolehkan		5,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA GUNUNG LINGAI	4							Jumlah Sampel = 3
Reservoir I (Air Produksi)		1,29	180,5	261,5	0	7,05	2,0	TMS = 0
Reservoir I (Air Produksi)	24	3,22	188,0	262,0	0	7,01	1,5	MS =
Reservoir I (Air Produksi)	30	1,71	181,0	255,0	6	7,07	1,4	Kekeruhan = 0
								Warna = 0
Januari 2023	tgl	Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	Keterangan
Parameter								
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl²	
Kadar Maksimum yang diperbolehkan		5,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA BENDANG	2							Jumlah sampel = 5
Reservoir I (Air Produksi)		4,72	54,10	76,30	8	6,80	2,0	TMS = 3
Reservoir I (Air Produksi)	9	5,40	51,25	72,45	15	6,77	1,4	MS = 2
Reservoir I (Air Produksi)	12	4,45	41,70	58,60	3	6,21	1,8	Kekeruhan = 3
Reservoir I (Air Produksi)	17	8,90	47,60	67,05	2	6,65	2,0	Warna = 0
Reservoir I (Air Produksi)	19	6,56	49,65	69,85	7	6,66	1,4	

Based on the summary results referring to Minister of Health Regulation No. 492 of 2010, samples were classified into those meeting the standards (MS) and not meeting the standards (TMS), as presented in the corresponding Tables 2 and Table 3.

Table 2. Summary of Turbidity Parameters Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES of 2010

No	Lokasi IPA Perumdam Tirta Kencana Kota Samarinda	Pengujian Parameter Kekeruhan (Jumlah Sampel)		
		Memenuhi Syarat (MS)	Tidak Memenuhi Syarat (TMS)	Total
1	IPA Cendana	74	16	90
2	IPA Tirta Kencana	86	55	141
3	IPA Seberang	37	11	48
4	IPA Palaran	37	11	48
5	IPA Selili	46	45	91
6	IPA Bengkuring	42	4	46
7	IPA Pulau Atas	15	28	43
8	IPA Gunung lipan	44	4	48
9	IPA Loa Bakung	38	8	46
10	IPA Gunung Lingai	44	1	45
11	IPA Bendang	26	21	47
12	IPA Bukuan	40	1	41
13	IPA Pampang	2	6	8
14	IPA Bentuas	6	2	8
15	IPA Makroman	40	4	44
16	IPA Sungai Kapih	36	10	46
17	IPA Kalhol	43	4	47
Total		656	231	887
Persentase (%)		73,96	26,04	100

Table 3. Example of Report Verification Results Based on Minister of Health Regulation No. 2 of 2023

Januari 2023+AA90:I110	tgl							Keterangan
Parameter		Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl^2	
Kadar Maksimum yang diperbolehkan		3,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA LIPAN	10							Jumlah sampel = 3
Reservoir I (Air Produksi)		3,08	53,10	74,75	12	6,95	1,4	MS = 1
Reservoir I (Air Produksi)	18	3,14	32,80	77,70	8	7,40	2,0	TMS = 2
Reservoir I (Air Produksi)	24	1,77	60,55	85,15	0	7,05	1,4	TMS kekeruhan = 2
								TMA Warna = 0
Januari 2023	tgl							Keterangan
Parameter		Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl^2	
Kadar Maksimum yang diperbolehkan		3,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA LOA BAKUNG	2							
Reservoir I (Air Produksi)		2,75	46,10	64,70	0	6,80	1,0	Jumlah sampel = 5
Reservoir I (Air Produksi)		3,00	54,55	76,65	17	6,86	1,4	MS = 1
Reservoir I (Air Produksi)		4,58	47,40	68,10	14	7,00	1,0	TMS = 4
Reservoir I (Air Produksi)		7,66	53,35	79,00	0	7,41	1,2	TMS kekeruhan = 3
Reservoir I (Air Produksi)		4,26	52,75	79,45	6	6,95	0,8	TMA Warna = 1
Januari 2023	tgl							Keterangan
Parameter		Kekeruhan	TDS	DHL	Warna	pH	Sisa Khlor	
Satuan		NTU	mg/l	µS/cm	PtCo	-	Cl^2	
Kadar Maksimum yang diperbolehkan		3,0	500	1500	15	6.5-8.5	0.20-5.00	
IPA GUNUNG LINGAI	4							Jumlah sampel = 3
Reservoir I (Air Produksi)		1,29	180,5	261,5	0	7,05	2,0	MS = 2
Reservoir I (Air Produksi)	24	3,22	188,0	262,0	0	7,01	1,5	TMS = 1
Reservoir I (Air Produksi)	30	1,71	181,0	255,0	6	7,07	1,4	TMS kekeruhan = 1
								TMA Warna = 0

Similarly, based on the summary results referring to Minister of Health Regulation No. 2 of 2023, samples were classified into MS and TMS, with the results shown in the respective Table 4 and Table 5.

Table 4. Summary of Turbidity Parameter Test Results Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023.

No	Lokasi IPA Perumdam Tirta Kencana Kota Samarinda	Pengujian Parameter Kekeruhan (Jumlah Sampel)		
		Memenuhi Syarat (MS)	Tidak Memenuhi Syarat (TMS)	Total
1	IPA Cendana	45	45	90
2	IPA Tirta Kencana	42	99	141
3	IPA Seberang	28	20	48
4	IPA Palaran	2	46	48
5	IPA Selili	26	65	91
6	IPA Bengkuring	35	11	46
7	IPA Pulau Atas	0	43	43
8	IPA Gunung lipan	39	9	48
9	IPA Loa Bakung	28	18	46
10	IPA Gunung Lingai	36	9	45
11	IPA Bendang	14	33	47
12	IPA Bukuan	33	8	41
13	IPA Pampang	1	7	8
14	IPA Bentuas	2	6	8
15	IPA Makroman	34	10	44
16	IPA Sungai Kapih	29	17	46
17	IPA Kalhol	41	6	47
Total		435	452	887
Persentase (%)		49,04	50,96	100

Table 5. Summary of Color Parameter Test Results Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023

No	Lokasi IPA Perumdam Tirta Kencana Kota Samarinda	Pengujian Parameter Warna (Jumlah Sampel)		
		Memenuhi Syarat (MS)	Tidak Memenuhi Syarat (TMS)	Total
1	IPA Cendana	82	8	90
2	IPA Tirta Kencana	136	5	141
3	IPA Seberang	46	2	48
4	IPA Palaran	46	2	48
5	IPA Selili	90	1	91
6	IPA Bengkuring	43	3	46
7	IPA Pulau Atas	41	2	43
8	IPA Gunung lipan	47	1	48
9	IPA Loa Bakung	45	1	46
10	IPA Gunung Lingai	44	1	45
11	IPA Bendang	43	4	47
12	IPA Bukuan	41	0	41
13	IPA Pampang	7	1	8
14	IPA Bentuas	8	0	8
15	IPA Makroman	44	0	44
16	IPA Sungai Kapih	43	3	46
17	IPA Kalhol	47	0	47
Total		853	34	887
Persentase (%)		96,17	3,83	100

Based on sampling and testing of physical parameters from 17 clean water treatment plants (IPAs) operated by Perumdam Tirta Kencana Samarinda City during the period January to November 2023, sample data were compiled from reports issued by the Central Laboratory of Perumdam Tirta Kencana Samarinda City. These reports included the total number of samples, samples meeting the standards (MS), and samples not meeting the standards (NMS), as presented in Tables IV.2 and IV.4. The test results were verified based on Minister of Health Regulation No. 492/MENKES of 2010 (Table IV.3) and Minister of Health Regulation No. 2 of 2023 (Table IV.5). The tables show that for each IPA, there were still physical parameters that did not meet the standards.

Over an 11-month monitoring period, from the total number of samples, 73.96% met the standards (MS) or had turbidity values below 5 NTU, while 26.04% did not meet the standards (NMS) or exceeded 5 NTU, based on Minister of Health Regulation No. 492/MENKES of 2010, which remained the reference for drinking water quality requirements in 2023. Meanwhile, based on Minister of Health Regulation No. 2 of 2023, which is to be fully implemented one to two years after its issuance, the data show that out of 887 samples, 435 samples (49.04%) met the standards (MS) or were below 3 NTU, whereas 452 samples (45.96%) did not meet the standards (TMS)

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3.2 Effectiveness of Filtration Media

The filtration experiment results indicate that both silica sand and activated carbon were capable of reducing turbidity and color values. However, activated carbon demonstrated higher effectiveness than silica sand across all media thickness variations. Increasing media thickness tended to enhance the percentage reduction in turbidity for both silica sand and activated carbon.

The test results for the color parameter, based on both Minister of Health Regulation No. 492/MENKES of 2010 and Minister of Health Regulation No. 2 of 2023, are identical, with a maximum standard of 15 PtCo, as shown in the summary presented in Table VI.6. Based on the recap of laboratory testing results from the Central Laboratory of Perumdam Tirta Kencana Samarinda City in 2023, out of 887 samples, 853 samples (96.17%) met the standards (MS) or were below 15 PtCo, while 34 samples (3.83%) did not meet the standards (NMS).

Other physical parameters such as temperature, total dissolved solids (TDS), total suspended solids (TSS), and electrical conductivity (EC) during the sampling and testing period, based on Minister of Health Regulation No. 2 of 2023, all met the required standards and therefore were not included in the summary tables.

The physical quality of clean water is primarily determined by turbidity and color, which are influenced by various environmental factors and human activities. Turbidity is generally caused by suspended particles such as silt, fine sand, organic matter, and microorganisms that enter water bodies due to soil erosion, surface runoff, or disturbances in the water distribution system (EPA, 2006). Meanwhile, water color typically originates from dissolved organic compounds such as humic and fulvic acids derived from the decomposition of natural organic matter in soil and vegetation (Sawyer et al., 2003). In addition, anthropogenic activities such as domestic and industrial wastewater discharge also contribute to increased turbidity and color, particularly when water treatment systems are not operating optimally. The quality of filtration media, contact time, and pH conditions also affect the effectiveness of reducing these parameters during the water treatment process (Tchobanoglous et al., 2003). Therefore, continuous monitoring and control of these factors are essential to ensure safe water quality that meets health standards.

3.3 Implications of Activated Carbon Use

Activated carbon is capable of reducing turbidity and color more significantly due to its adsorption mechanism on a large pore surface area, making it effective in binding fine particles and dissolved organic compounds. These results are consistent with previous studies that have reported the effectiveness of activated carbon in improving the physical quality of drinking water.

The use of activated carbon as a filtration medium, either as a replacement for or as an additional medium following silica sand filtration, has the potential to improve the quality of drinking water produced by the IPAs operated by Perumdam Tirta Kencana. The application of this medium must be accompanied by proper operational management, including control of contact time and periodic media replacement to prevent adsorption saturation.

The objective of the activated carbon filtration experiment was to evaluate its comparative effectiveness against silica sand in reducing physical parameters after sedimentation and filtration stages in clean water treatment plants, particularly turbidity (NTU) and color (PtCo) parameters. The ultimate goal was to achieve turbidity levels that comply with the drinking water standards stipulated in Minister of Health Regulation No. 2 of 2023.

Based on the treatment results presented in Table V.1, the comparison between silica sand filter media with varying thicknesses—P1, P2, and P3 (10 cm, 20 cm, and 30 cm, respectively)—and activated carbon filter media with thicknesses A1, A2, and A3 (10 cm, 20 cm, and 30 cm, respectively), conducted over three experimental runs, showed changes in physical parameters, particularly turbidity and color, as observed from the influent and effluent values.

The effectiveness was calculated using the following equation:

$$\text{Effectiveness} = (I_i - I_o) \times 100\,\%/I_o$$

Where:

I_i = initial/input parameter value
I_o = final/output parameter value

Based on the experimental results and the effectiveness calculation, the results are summarized in the corresponding Table 6.

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Table 6. Results of Effectiveness Calculation for Turbidity Reduction

MEDIA	KETETEBALAN	PERLAKUAN I KEKERUHAN(NTU) In	PERLAKUAN I KEKERUHAN(NTU) Out	PERLAKUAN I Efektivitas (%)	PERLAKUAN II KEKERUHAN(NTU) In	PERLAKUAN II KEKERUHAN(NTU) Out	PERLAKUAN II Efektivitas (%)	PERLAKUAN III KEKERUHAN(NTU) In	PERLAKUAN III KEKERUHAN(NTU) Out	PERLAKUAN III Efektivitas (%)	Total Efektivitas (%)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[5+8+11]
P1	10 cm	3,39	3,57	- 5,31	3,27	2,02	38,23	5,64	3,85	31,74	64,65
P2	20 cm	3,39	3,39	-	3,27	1,79	45,26	5,64	3,5	37,94	83,20
P3	30 cm	3,39	3,04	10,32	3,27	1,66	49,24	5,64	2,74	51,42	110,98
A1	10 cm	3,39	3,05	10,03	3,27	0,35	89,30	5,64	4,75	15,78	115,11
A2	20 cm	3,39	2,3	32,15	3,27	0,33	89,91	5,64	3,82	32,27	154,33
A3	30 cm	3,39	2,42	28,61	3,27	0,33	89,91	5,64	2,77	50,89	169,41

Notes:
P1, P2, P3 = Silica sand media with thicknesses of 10 cm, 20 cm, and 30 cm
A1, A2, A3 = Activated carbon media with thicknesses of 10 cm, 20 cm, and 30 cm

A descriptive analysis indicates that, based on Table V.1, the effectiveness of turbidity reduction using activated carbon was significantly higher than that of silica sand. For example, in Treatments I, II, and III at a media thickness of 10 cm, the total turbidity reduction effectiveness for silica sand (P1) was 64.65%, whereas activated carbon (A1) achieved 115.11%. Similar trends were observed for media thicknesses of 20 cm and 30 cm. Thus, activated carbon can be considered more effective than silica sand as a filtration medium for turbidity reduction.

Specifically for turbidity over the three treatment runs, Treatments I and II showed that activated carbon was more effective in reducing turbidity than silica sand, while Treatment III exhibited a similar trend for both media. Increasing media thickness for both media types resulted in greater turbidity reduction.

For the color parameter, using the same analytical approach, the effectiveness of color reduction by comparing silica sand and activated carbon media is presented in Table 7.

Table 7. Effectiveness of Color Parameter Reduction

MEDIA	KETETEBALAN	PERLAKUAN I WARNA(PtCo) In	PERLAKUAN I WARNA(PtCo) Out	PERLAKUAN I Efektivitas (%)	PERLAKUAN II WARNA(PtCo) In	PERLAKUAN II WARNA(PtCo) Out	PERLAKUAN II Efektivitas (%)	PERLAKUAN III WARNA(PtCo) In	PERLAKUAN III WARNA(PtCo) Out	PERLAKUAN III Efektivitas (%)	Total Efektivitas (%)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[5+8+11]
P1	10 cm	3	10	- 233,33	7	6	14,29	6	11	- 83,33	- 302,38
P2	20 cm	3	12	- 300,00	7	7	-	6	6	-	- 300,00
P3	30 cm	3	4	- 33,33	7	6	14,29	6	10	- 66,67	- 85,71
A1	10 cm	3	6	- 100,00	7	6	14,29	6	10	- 66,67	- 152,38
A2	20 cm	3	9	- 200,00	7	5	28,57	6	10	- 66,67	- 238,10
A3	30 cm	3	7	- 133,33	7	5	28,57	6	9	- 50,00	- 154,76

The testing conditions for the color parameter for both media showed a general tendency toward an increase, except during the second experiment using activated carbon, which exhibited a decrease. For silica sand media, this phenomenon is attributed to the presence of particles containing organic matter, inorganic materials, metal ions such as iron (Fe), and other substances (Munfiah & Setiani, 2013). Media thickness did not significantly influence changes in output color values. Based on the experimental results, activated carbon demonstrated superior performance in color reduction. Although there was a tendency for slight increases in color values, the results still met the quality standards stipulated in Minister of Health Regulation No. 2 of 2023. Activated carbon is therefore highly effective as a filtration medium for reducing color and turbidity in drinking water treatment at PDAM facilities. Its effectiveness depends on process design and raw water quality; however, in general, it provides a significant improvement in water quality to meet drinking water standards.

4. Conclusion

The physical quality parameters of drinking water after filtration from the 17 IPAs operated by Perumdam Tirta Kencana Samarinda City, based on periodic monitoring during 2023, still showed several parameters that did not meet the applicable standards according to Minister of Health Regulation No. 492 of 2010, which remained the reference for drinking water quality requirements during that year. The physical parameters of concern were turbidity and color. Periodic monitoring results indicated that turbidity levels exceeding 5 NTU were still detected in the effluent of several IPAs. Similarly, although in small numbers, some color values still exceeded 15 PtCo.

Activated carbon was proven to be more effective than silica sand in reducing turbidity and color parameters. The use of activated carbon is therefore recommended as an alternative filtration medium, either partially, in combination with silica sand, or as a post-filtration treatment, to address specific raw water quality issues at the IPAs operated by Perumdam Tirta Kencana.

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