

Gema Lingkungan Kesehatan

Vol. 24, No. 1 (2026), pp 97-107

e-ISSN 2407-8948 p-ISSN 16933761

doi: <https://doi.org/10.36568/gelinkes.v24i1.375>Journal Homepage: <https://gelinkes.poltekkesdepkes-sby.ac.id/>

Assessment of Water Quality in Rural Drinking Water Supply Systems in Yogyakarta

Rif'atunnisa^{1*}, Ni Nyoman Nepi Marleni², Budi Kamulyan²¹ Master of Civil Engineering Program, Department of Civil and Environmental Engineering, Faculty of Engineering, Gadjah Mada University, Yogyakarta, Indonesia² Department of Civil and Environmental Engineering, Faculty of Engineering Gadjah Mada University, Yogyakarta, Indonesia*Correspondence: rifatunnisa1997@gmail.com

Access to safe drinking water in rural areas remains a global public health challenge, especially in Indonesia. This study evaluates the water quality of the Tirta Wening Rural Drinking Water Supply System in Kulon Progo Regency, Special Region of Yogyakarta, which operates two treatment facilities: SPAM 1 and SPAM 2. In order to assess each network's compliance with national quality standards for drinking water, a total of twelve quality parameters were measured at six different water sampling points. These parameters include: (1) physical properties—temperature, turbidity, color, odor, total dissolved solids/TDS; (2) chemical concentrations—pH, nitrite, nitrate, iron, manganese; (3) microbiological contaminations—*E. coli*, total coliform. The results show that the physical and chemical parameters have already aligned with their standards, except for TDS and manganese concentrations. There are two sampling points in SPAM 1 and five points in SPAM 2 that have a higher TDS than the permissible concentration of 300 mg/L. The manganese concentrations exceed the maximum standard of 0.1 mg/L at one sampling point in SPAM 1 and three points in SPAM 2. In terms of microbiological parameter, *E. coli* contamination was found at four sampling points in SPAM 1 and all points in SPAM 2, and total coliform exceeds 300 CFU/100 mL at almost all the sampling points. These findings highlight the need for improved treatment, routine monitoring, and household-level solutions to meet national drinking water quality standards.

Keywords: Rural Drinking Water Supply System, Water Quality, Water Treatment**INTRODUCTION**

Providing clean and safe drinking water is necessary for maintaining public health and supporting social and economic development. Access to adequate drinking water can improve quality of life, reduce the risk of waterborne diseases, and provide comfort in daily life (Lahay et al., 2024). In the Special Region of Yogyakarta, rural communities access drinking water through the Rural Drinking Water Supply System(s) (RDWSS) managed by community groups. The existence of these systems shows a great potential in meeting the basic demand for drinking water in rural areas; however, their management still faces various challenges.

One of the main challenges in managing RDWSS is ensuring that the drinking water meets the safety and quality standards. According to the 2023's monitoring report by the Health Department of Kulon Progo Regency, only 5.69% of the drinking water facilities complied with the safety standards of the Regulation of the Indonesian Ministry of Health No. 3 of 2023. As a technical solution, Point-of-Use (PoU) and Point-of-Entry (PoE) systems can be implemented to help meet drinking water quality

standards. The PoE system is a centralized water treatment method that processes the water before it is distributed to households. In contrast, the PoU system is applied at the household level and treats the water at specific use points, such as taps used for drinking or cooking (Lahlou, 2018; Sombei et al., 2025; Wu et al., 2021).

The Tirta Wening RDWSS is a PoE-based RDWSS in Kulon Progo Regency that has two treatment facilities locally known as SPAM (*Sistem Penyedia Air Minum*/Drinking Water Supply System), namely SPAM 1 and SPAM 2. SPAM 1 utilizes a water treatment plant (WTP) equipped with carbon sand filters and ultraviolet light technology to serve the Kemiri and Rejoso Hamlets. According to the management of Tirta Wening RDWSS, water quality inspections on SPAM 1 are conducted monthly at the WTP's outlet. Meanwhile, SPAM 2 utilizes a simpler water treatment system consisting of coconut fiber filters, gravel, and sand to serve the Setan, Wijilan, and Dukuh Hamlets. To date, no water quality inspections have been conducted on this network. These RDWSS's conditions indicate that quality issues still exist in ensuring safe water quality for

customers.

Research on water quality across rural water supply systems—from source to reservoir to household connection—is still limited, with few studies combining service performance with systematic quality monitoring and household insights (Adedotun et al., 2024; Bolatova et al., 2025; Nowicki et al., 2020). In fact, water quality evaluations for RDWSS are typically conducted at only one sampling point, in spite of that water quality can vary along the distribution network. Moreover, water quality degradation can often occur due to poor condition of the pipeline, activities around the water source, or when water is stored before used (Barid et al., 2025; Świetlik & Magnucka, 2025). On the other hand, water quality also influences public interest in becoming a treatment plant's customers (Zikrina et al., 2024). Therefore, evaluating water quality at various distribution points is crucial to determine how effective can the management system function, while ensuring that the water received by customers meets the water quality standards for safe drinking stated in the Regulation of the Indonesian Ministry of Health No. 3 of 2023.

This study aims to determine water quality at

several points within the Tirta Wening RDWSS's treatment facilities (SPAM 1 and SPAM 2) to assess compliance with national drinking water quality standards, from the water source to customers' taps. The indicators used in this study include physical, chemical, and microbiological parameters. The results of this study are expected to provide recommendations that contribute to improving water quality within the Tirta Wening RDWSS.

METHOD

This study uses a descriptive quantitative approach to determine the water quality in the distribution networks of the Tirta Wening RDWSS's SPAM 1 and SPAM 2. The research consisted of customer data collection, water sampling, laboratory test on the water sample, and the result analysis. Primary data were obtained through questionnaires distributed to customers, which provided insights into their characteristics and patterns of drinking water consumption. Additionally, water samples were collected from various points within SPAM 1 and SPAM 2's distribution networks, of which the schemes are shown respectively in Figures 1 and 2.

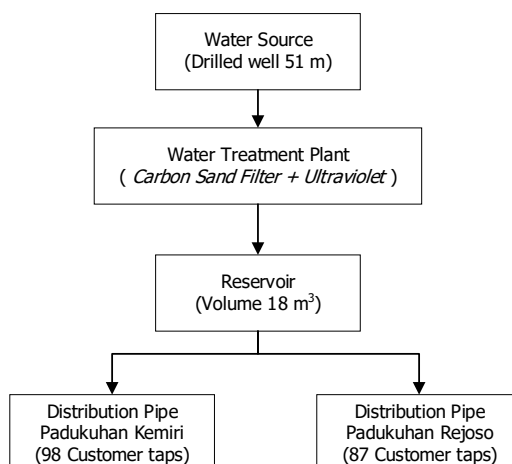


Figure 1. Distribution Network of Tirta Wening RDWSS's SPAM 1

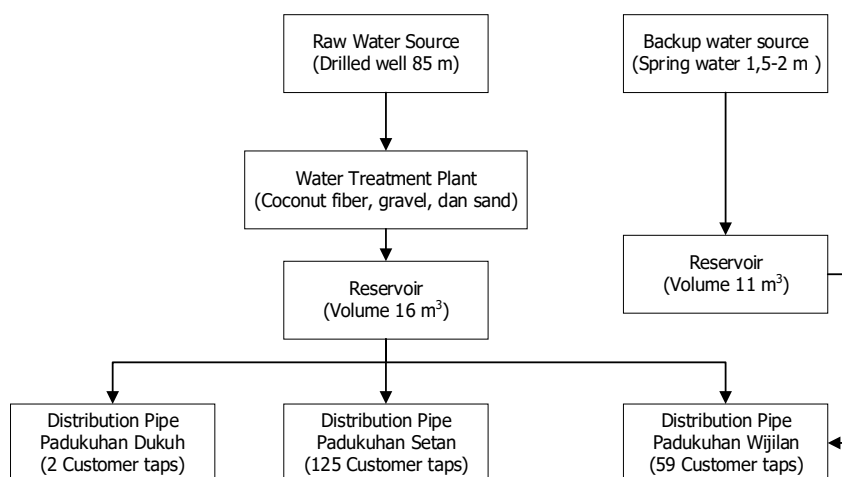


Figure 2. Distribution Network of Tirta Wening RDWSS's SPAM 2

The sampling locations were determined using a purposive sampling approach, which involves selecting

points based on specific considerations deemed representative of various stages in the distribution system.

This location determination was based on Indonesian National Standard (*Standar Nasional Indonesia/SNI*) 9063:2022 and SNI 8995:2021 regarding sample collection procedures of water quality testing. For each SPAM 1 and SPAM 2, a total of 12 points were selected as sampling locations. These points included: source of raw water, WTP's inlet, WTP's outlet, and three customer taps located at different distances from the WTP. The taps were categorized based on their distance from the WTP, namely nearest, middle, and farthest taps. The nearest tap was located within a radius of 0–100 meters from the WTP, the

middle tap was approximately 300–600 meters away, and the farthest tap was situated at the end of the pipeline, around 700–1000 meters from the WTP (see Table 1). It should be noted that sampling at the source of raw water of SPAM 2 could not be conducted because there were no tap facilities and the area was covered with concrete slabs. However, since the SPAM 2's WTP's inlet and the source of raw water are located in the same location, water samples from the WTP's inlet are assumed representative of those from the source of raw water.

Table 1.
UTM Coordinates of Sampling Points

Distribution Network	Sample Code	Sampling Point	Coordinates
SPAM 1	1	Raw Water Source	-7.791971°, 110.221940°
	2	WTP's Inlet	-7.789800°, 110.221863°
	3	WTP's Outlet	-7.789800°, 110.221863°
	4	Nearest Customer Tap (SR 1)	-7.790044°, 110.221763°
	5	Middle Customer Tap (SR 2)	-7.793153°, 110.220696°
	6	Farthest Customer Tap (SR 3)	-7.791363°, 110.215874°
SPAM 2	7	WTP's Inlet	-7.791752°, 110.225613°
	8	WTP's Outlet	-7.791752°, 110.225613°
	9	Nearest Customer Tap (SR 4)	-7.792421°, 110.226166°
	10	Middle Customer Tap (SR 5)	-7.796220°, 110.227583°
	11	Farthest Customer Tap (SR 6)	-7.796091°, 110.233374°
	12	Backup Water Source	-7.797282°, 110.227320°

The sampling procedure follows SNI 8995:2021 for water sampling methods in physical and chemical testing, and SNI 9063:2022 for water and liquid waste sampling methods in microbiological parameter testing. Samples are taken once from each point using the grab sampling method, which involves collecting a sample at a specific time and location without mixing it with other samples. This aims to provide an accurate representation of water quality at the time of sampling. The sampling itself was conducted on August 12, 2024, between 09:13 and 13:14 local time (WIB). To ensure the validity of the results, samples were packaged in sterile containers and stored at low temperatures during transportation to the laboratory. Physical and chemical parameter testing was conducted at

the Universitas Gadjah Mada's Environmental Health Engineering Laboratory, while microbiological parameters were tested at the Kulon Progo Regency's Health Laboratory.

The laboratory tests were performed using the methods specified in the Indonesian Ministry of Health No. 3 of 2023. The physical parameters analyzed included temperature, total dissolved solids (TDS), turbidity, color, and odor. The chemical parameters included pH, nitrate, nitrite, iron, and manganese. The microbiological parameters tested were the presence of *E. coli* and total coliform. Table A1 shows the parameters tested and the testing methods used in this study.

Tabel A1.
Detail of Testing Parameters, Equipment Used, and Testing Method

Testing Parameter	Unit	Standard Reference	Equipment Used	Testing Method
Physical Temperature	°C	Air temp. ± 3	Alcohol thermometer	In situ

Testing Parameter	Unit	Standard Reference	Equipment Used	Testing Method
Total dissolved solids	mg/L	<300	Portable Multi-parameter HACH SensION 156	Potentiometry
Turbidity	NTU	<3	Turbidimeter HACH 2100Q	SNI 06-6989.25-2005
Color	TCU	10	LaMOTTE - TC 3000e	
Odor	-	Odorless	Organoleptic	
Chemical				
pH	-	6.5–8.5	Portable Multi-parameter HACH SensION 156	SNI 6989.11:2019
Nitrate	mg/L	20	Spectrophotometer HACH DR 2010	SNI 6989.79:2011
Nitrite	mg/L	3	Spectrophotometer HACH DR 2010	SNI 06-6989.9-2004
Iron (Fe)	mg/L	0.2	Spectrophotometer HACH DR 2010	SNI 06-4138-1996
Manganese (Mn)	mg/L	0.1	Spectrophotometer HACH DR 2010	SNI 06-6855-2002
Microbiological				
<i>E. coli</i>	CFU/100 mL	0	Filter membrane	SNI 9308-1-2010
Total coliform	CFU/100 mL	0	Filter membrane	SNI 9308-1-2010

The data were analyzed descriptively to provide a comprehensive overview of water quality at each sampling point. The analysis results were then compared to the quality standards outlined in the Regulation of the Indonesian Ministry of Health No. 3 of 2023 to assess the treatment facilities' compliance with these established standards. Additionally, the effectiveness of the WTP in removing water quality parameters was evaluated by measuring changes in water quality from the inlet to the outlet. This evaluation aims to determine how effectively the PoE system improved water quality before being distributed to customers.

RESULTS AND DISCUSSION

A total of 95 respondents participated in this survey, all of whom were registered customers of the Tirta Wening RDWSS. The survey results indicated that most respondents were between 41 and 60 years old. Most of them had completed high school, and their primary occupations (farming and household work) reflect a typical socio-economic structure of rural communities. Most respondents reported a monthly income of less than 500,000 IDR. It can be seen in Table 2 that the average household size was three to four members. This indicates a relatively high demand for domestic water supply.

Table 2.

Characteristics Recapitulation of the Questionnaires Respondents on the Drinking Water Consumption of the Tirta Wening RDWSS

	Characteristics	Number of Respondents	Percentage
Age (year)	21-30	4	4%
	31-40	7	7%
	41-50	26	27%
	51-60	25	26%
	61-70	21	22%
	>70	12	13%
Level of education	No schooling	1	1%
	Elementary school	17	18%
	Junior high school	10	11%
	Senior high school	41	43%
	Diploma/Bachelor's degree	26	27%
Occupation	Not working	11	12%
	Housework	14	15%
	Farmer	16	17%
	Entrepreneur, trader	13	14%
	Civil servant, teacher	5	5%
	Private employee, temporary employee	10	11%
	Laborer, craftsman, odd jobber	15	16%
	Retired	9	9%
	Other	2	2%

Income	Below Rp 500,000	33	35%
	Rp 500,001 - Rp 1,000,000	21	22%
	Rp 1,000,001 - Rp 1,500,000	9	9%
	Rp 1,500,001 - Rp 2,000,000	8	8%
	Rp 2,000,000 and above	24	25%
Number of family members	1-2 people	23	24%
	3-4 people	45	47%
	5-6 people	24	25%
	>6 people	3	3%

Based on the respondents' perceptions, the overall quality of water is considered quite good, especially regarding clarity, smell, and taste. Most customers believe the water is suitable for everyday use, indicating a general positive assessment. However, some respondents provided neutral feedback, indicating that they did not perceive the water as either poor or excellent. This could stem from their familiarity with the water or limited knowledge of water quality standards. A few respondents

expressed concerns about the water quality, particularly regarding odor and clarity. The water is primarily utilized for washing, bathing, flushing toilets, and watering plants, with its application for cooking and drinking being relatively low. This may reflect the community's hesitation about the water's suitability for direct consumption. An overview of customer perceptions regarding water quality and usage patterns is illustrated in Figures 3 and 4.

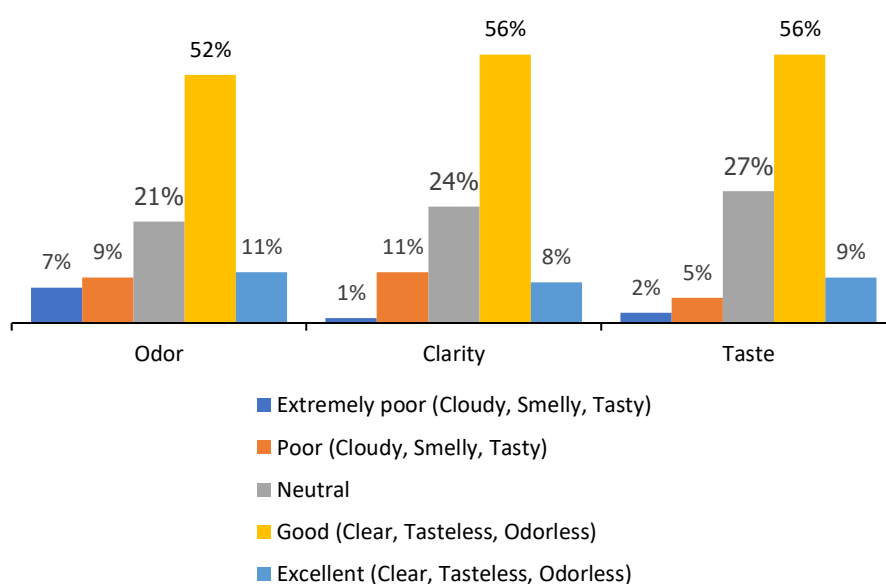


Figure 3. Customers' perceptions on the water's clarity, odor, and taste in the Tirta Wening RDWSS

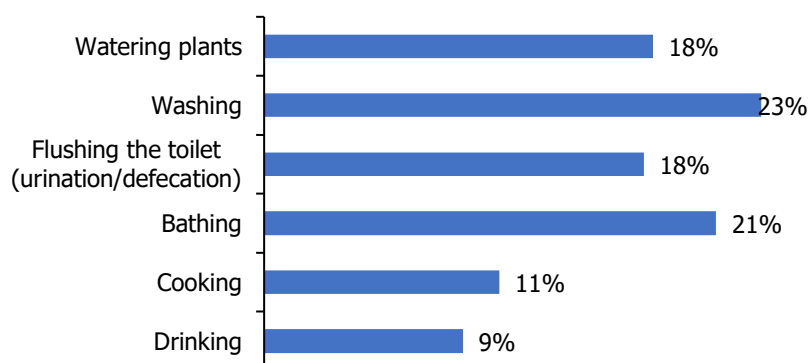


Figure 4. Water Usage of the Tirta Wening RDWSS

Water Quality in SPAM 1

SPAM 1 provides water to 185 customers in the Kemiri and Rejoso Hamlets. The area of these hamlets is characterized by houses that are not densely populated, featuring large yards surrounded by gardens and animals

such as chickens, dogs, and cats. According to the management of Tirta Wening RDWSS, the system provides water that meets drinking water quality standards. Some residents purchase water directly from the WTP's outlet for Rp. 2,000.00 per gallon. Monthly test results indicate that

the TDS exceeded the quality standard. Despite this, many residents continue to use the water from the WTP's outlet for direct consumption or resale. Interestingly, some customers still choose to boil the water before consuming it, even though they know it has been treated with a carbon sand filter and UV technology.

As of this study, it can be seen in Table 3 that the quality of drinking water in SPAM 1 vary at various sampling points, with several parameters exceeding the established quality standards. In terms of physical parameter, the water temperature at all sampling points fluctuated between 27°C and 30.3°C and was within the acceptable range according to the quality standards (28 ± 3°C). Temperature decreases after treatment at the WTP, but increases again at some customer tap points. This may be due to environmental factors such as sunlight exposure and shaded conditions at the sampling locations. Meanwhile, the TDS generally remained within the permissible quality standards (<300 mg/L), except at the

WTP outlet (305 mg/L) and the SR 2 customer outlet (333 mg/L), which exceeded the quality standards. The increase in TDS at the WTP's outlet is suspected to be due to insufficient membrane maintenance, which, according to the operator, is only replaced every six months or when water pressure decreases, potentially causing blockages. High TDS levels at the WTP may be caused by membrane blockages, hindering filtration and preventing dissolved substances from being filtered optimally (Haider et al., 2021). The condition of the faucet at SR 2, which appears to be scaled, also reinforces the indication of high TDS. TDS exceeding about 500 mg/L (ppm) are associated with increased mineral scale formation in pipelines and household systems, which can reduce the efficiency and lifespan of appliances such as water heaters and boilers (Adjovu et al., 2023; Amin et al., 2024). On the other hand, turbidity, color, and odor parameters showed good results at all sampling points, as shown in Table A2.

Tabel A2.
Secondary Quality Parameters of Drinking Water in the Tirta Wening RDWSS's SPAM 1

Parameter	Quality Standard	Test Results					
		Raw Water Source	WTP's Inlet	WTP's Outlet	SR 1	SR 2	SR 3
Temperature (°C)	28±3	30.3	29.0	27.0	30.0	29.8	27.0
Turbidity (NTU)	<3	1.05	0.23	0.32	0.25	0.32	0.37
Color (TCU)	10	0.90	1.20	0.90	1.65	2.10	0.30
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
Nitrate (mg/L)	20	1.73	2.33	1.83	3.07	2.47	2.30
Nitrite (mg/L)	3	0.012	0.033	0.012	0.013	0.016	0.014
Iron (mg/L)	0.2	0.04	0.01	0.00	0.01	0.02	0.03

From the chemical parameters, the water quality at SPAM 1 shows relatively good conditions. Table 3 shows that the pH value is within the range of 6.9–7.7, in line with the quality standard (6.5–8.5). Similarly, nitrate, nitrite, and iron levels are far below the quality standard, as shown Table A2. This indicates minimal nitrogen and heavy metal contamination. However, manganese levels exceed the quality standard at the WTP's inlet with a value of 0.2 mg/L (quality standard 0.1 mg/L). This condition is suspected to be caused by leaks in the transmission pipes from the water source to the WTP. Nevertheless, overall water quality from a chemical perspective remains good up to the customer tap, making the water suitable for consumption.

Unlike the physical and chemical parameters, microbiological parameters indicate contamination throughout the distribution network. Table 3 shows that *E. coli* level reached 10 CFU/100 mL at the WTP's inlet, indicating contamination from pipeline leaks. *E. coli* was not detected at the WTP's outlet, indicating the WTP's excellent performance in removing *E. coli*. However, contamination reoccurred in the distribution system, with *E. coli* levels of

8 CFU/100 mL at the nearest customer, 18 CFU/100 mL at the midpoint customer, and significantly increasing to 104 CFU/100 mL at the farthest customer. Total coliform also showed very high values (too numerous to count/ TNTC) at several points, including the water source, the WTP's inlet, SR 2, and SR 3. This microbiological contamination could be caused by several factors: (1) leaks or breaches in transmission pipes can allow microorganisms from the environment to enter the network and elevate contamination levels (pressure transients and leak events increase pathogen intrusion risk) (Odhiambo et al., 2023); (2) pipe materials such as PVC may support biofilm formation and microbial colonization on internal surfaces, influencing microbial stability in the network (Stefan et al., 2023); (3) very low flow rates at distant customers support stagnant conditions that promote biofilm persistence and microbial growth, raising the risk of *E. coli* contamination (Alhoshy et al., 2025); (4) sudden drops in pipe pressure can draw contaminated external water into the system, further introducing *E. coli* and other microbes (negative and low pressure events are known to enable contaminant intrusion) (Vacs Renwick et al., 2019).

Table 3.
Primary Quality Parameters of Drinking Water in the Tirta Wening RDWSS's SPAM 1

Parameter	Quality Standard	Test Result					
		Raw Water Source	WTP's Inlet	WTP's Outlet	SR1	SR 2	SR 3
Total Dissolved Solids (mg/L)	<300	297	289	305	279	333	276
pH	6.5–8.5	6.9	7.5	7.4	7.7	7.6	7.5
Manganese (mg/L)	0.1	0.1	0.2	0.1	0.1	0.1	0.1
<i>E. coli</i> (CFU/100 mL)	0	0	10	0	8	18	104
Total coliform (CFU/100 mL)	0	TNTC*)	TNTC	0	110	TNTC	TNTC

*) : Too numerous to count (there are more than 300 colonies/100mL)

Water Quality in SPAM 2

SPAM 2 serves 185 customers in Setan, Wijilan, and Dukuh Hamlets. The environmental conditions in these three hamlets are similar to those in Kemiri and Rejoso Hamlets, where rice fields surround the area and residents' houses are surrounded by banana and mango orchards. However, this area is more densely populated and has broader water network coverage. The management of Tirta Wening RDWWS does not routinely monitor water quality, but only ensures the water supply remains available. This water network system has two raw water

sources: boreholes and springs (Figure 2). The springs are a backup water source stored in a reservoir tank, and the system is designed to operate automatically. If the primary raw water source experiences a shortage, especially for the Wijilan area, water from the springs will be automatically diverted.

In this study, the quality test results of the water in SPAM 2 show differences in water quality at several points. Physical parameters like color, odor, and turbidity remain within the specified quality standards, as shown in Table A3.

Tabel A3.
Secondary Quality Parameters of Drinking Water in the Tirta Wening RDWSS's SPAM 2

Parameter	Quality Standard	Test Results					Backup Water Source
		WTP Inlet	WTP outlet	SR 4	SR 5	SR 6	
Temperature (°C)	28±3	29.8	30.0	31.5	29.8	29.0	28.3
Turbidity (NTU)	<3	0.70	0.64	0.71	0.65	0.96	1.02
Color (TCU)	10	3.80	2.85	2.50	2.00	1.60	1.70
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
Nitrate (mg/L)	20	1.70	1.87	2.40	3.03	3.13	3.67
Nitrite (mg/L)	3	0.014	0.015	0.021	0.015	0.017	0.015
Iron (mg/L)	0.2	0.14	0.09	0.07	0.04	0.03	0.02

However, it can be seen in Table 4 that the TDS concentrations at all sampling points exceed the standard maximum of 300 mg/L. Although there was a slight decrease in TDS values along the distribution network, the difference was minimal, where the decrease in the WTP was only 1 mg/L. This indicates that the treatment process is not yet operating optimally. Conversely, the source of backup water (a spring) showed a TDS concentration of 127 mg/L. Such conditions could be caused by rainwater entering the unprotected source. Rainwater has naturally low TDS, often well below typical drinking water values, with recent studies reporting levels in the range of 14–38 mg/L under field conditions, which helps explain the lower TDS observed at the spring when mixed with rain input (Khalid & Alodah, 2023). Moreover, TDS levels often remain largely unchanged along drinking water

distribution systems, which reflects the limited effectiveness of conventional treatment processes in removing TDS (Domoń et al., 2025; Hassan et al., 2025; Zhou et al., 2023).

Chemical parameters such as nitrate, nitrite, and iron are below the established quality standards (Table A3). The pH values at all sampling points meet the quality standards, except for the pH value at the source of backup water, which is recorded at 5.9, below the established quality standard range of 6.5–8.5. This low pH is suspected to be caused by the entry of acidic rainwater into the water source, particularly due to the absence of a cover on the water source. Rainwater typically has a pH of around 5.0–5.8, resulting from interaction with carbon dioxide (CO₂) in the atmosphere (Huang et al., 2024). Meanwhile, manganese concentrations exceed the limit at

several points, namely at the WTP's inlet and outlet and SR 4. These high manganese concentrations may be caused by local geological conditions, particularly from the weathering of sedimentary rocks that release manganese minerals such as pyrolusite and manganite, as well as from oxygen-deficient groundwater conditions (Hamidah & Cindramawa, 2020). There was no significant reduction in manganese concentration during the treatment process at the WTP. This indicates that the filtration system used is not yet sufficiently effective. The composition of the filter media can also influence the efficiency of reducing manganese concentrations in raw water (Propolsky & Romanovski, 2025; Shrestha et al., 2024).

Regarding microbiological parameters, all sampling points showed microbiological contamination, with *E. coli* counts varying between 5 and 33 CFU/100 mL, far ex-

ceeding the quality standard (0 CFU/100 mL). This condition is primarily caused by the absence of disinfection processes or the use of ultraviolet (UV) light in the treatment system of the SPAM 2 network. Additionally, the total coliform parameter at all sampling points was recorded as TNTC, indicating extremely high contamination levels. Field observations revealed several factors that could exacerbate this condition. These include: (1) Treatment tanks overgrown with algae; (2) Rarely replaced or cleaned filters; (3) Distribution pipes and customer taps that appear poorly maintained. The customers' home environment can also contribute to high microbiological contamination, particularly in households that keep livestock near the sources of water have inadequate sanitation.

Table 4.
Primary Quality Parameters of Drinking Water in the Tirta Wening RDWSS's SPAM 2

Parameter	Quality Standard	Test Result						
		WTP Inlet	WTP Outlet	SR 4	SR 5	SR 6	Backup Water Source	
Total Dissolved Solids (mg/L)	<300	390	389	387	385	350	127	
pH	6.5–8.5	6.9	7.0	7.4	7.4	7.0	5.9	
Manganese (mg/L)	0.1	0.3	0.2	0.2	0.1	0.1	0.1	
<i>E. coli</i> (CFU/100 mL)	0	21	33	26	28	9	5	
Total coliform (CFU/100 mL)	0	TNTC*)	TNTC	TNTC	TNTC	TNTC	TNTC	

*) : Too numerous to count (there are more than 300 colonies/100mL)

Performance Comparison between the SPAM 1 and SPAM 2's WTPs

The differences in technology applied to the two water treatment systems affect the efficiency of removing various water quality parameters. The SPAM 1's WTP uses a carbon sand filter equipped with ultraviolet light. In

contrast, SPAM 2's WTP combines coconut fiber, gravel, and sand as a filtration method. Based on the results of water quality tests, the WTP performances of SPAM 1 and SPAM 2 were compared using physical, chemical, and microbiological parameters.

Table 5.
Performance Comparison between the Water Treatment Plants of the Tirta Wening RDWSS's SPAM 1 and SPAM 2

Parameter	SPAM 1's WTP		SPAM 2's WTP	
	Inlet	Outlet	Inlet	Outlet
Temperature (°C)	29	27	29.8	30
Total Dissolved Solids (mg/L)	289	305	390	389
Turbidity (NTU)	0.23	0.32	0.70	0.64
Color (TCU)	1.20	0.9	3.8	2.85
pH	7.49	7.41	6.90	7.03
Nitrate (mg/L)	0.033	0.012	0.014	0.015
Nitrite (mg/L)	2.3	1.8	1.7	1.9
Iron (mg/L)	0.01	0.00	0.14	0.09
Manganese (mg/L)	0.2	0.1	0.3	0.2
<i>E. coli</i> (CFU/100 mL)	10	0	21	33
Total coliform (CFU/100 mL)	TNTC*)	0	TNTC	TNTC

*) : Too numerous to count (there are more than 300 colonies/100mL)

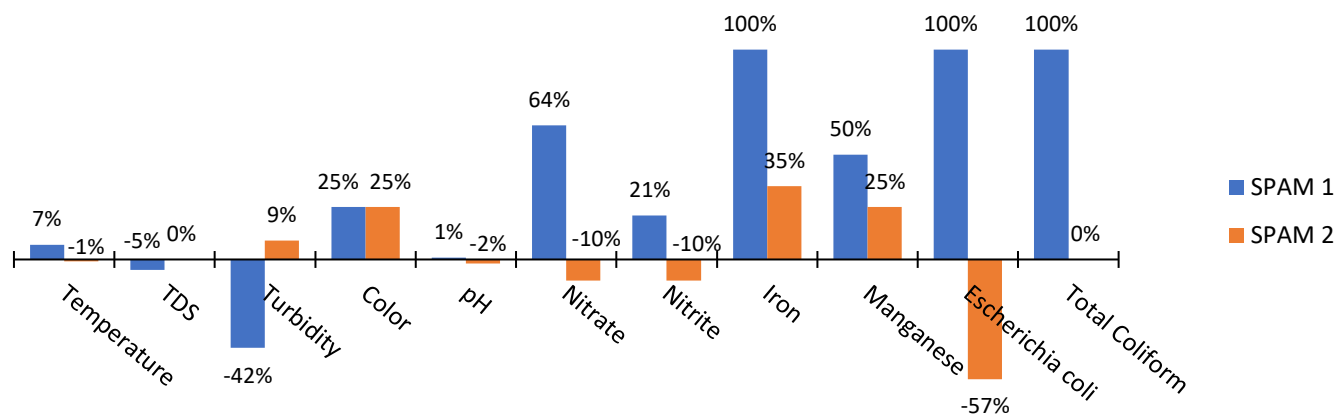


Figure 5. Removal Efficiency Comparison between the Water Treatment Plants of the Tirta Wening RDWWS's SPAM 1 and SPAM 2

As shown in Table 5 and Figure 5, the SPAM 1's WTP can remove *E. coli*, total coliform, and iron (Fe) with a reduction rate of 100%. SPAM 1 also successfully reduced Nitrite by 64%, Nitrate by 21%, Manganese (Mn) by 50%, and color by 25%. UV light has long been proven to be highly effective in reducing the number of *E. coli* and total coliform to undetectable levels. It is highly effective in inactivating various microorganisms, including bacteria such as *E. coli* and total coliform, with removal efficiency up to 100% (Nazar & Al-Musawi, 2021). Meanwhile, the Carbon Sand Filter combination, consisting of gravel, sand, and carbon, is crucial in removing heavy metals such as Fe and Mn. Activated carbon in the filtration process functions as an adsorbent that can adsorb certain gases and chemical compounds, including Fe and Mn (Anifah et al., 2024; Elewa et al., 2023). However, the SPAM 1's WTP failed to reduce the TDS concentration, with an increase of 5% after filtration. Additionally, turbidity levels also increased by 42%. This condition is suspected to be caused by the lack of regular backwashing, which lead to the accumulation of sediment particles and filter media saturation. The accumulation of contaminant particles in the filter media can reduce filtration effectiveness, as pollutants that should be filtered out are trapped and accumulated in the media (Nawiswary & Tangahu, 2023). Therefore, regular backwashing is essential to restore the performance of the filter media and maintain its effectiveness in water treatment (Duran-Ros et al., 2024).

On the other hand, the SPAM 2's WTP, which uses a simple filtration system with a media arrangement consisting of coconut fiber, gravel, and sand, demonstrates sufficient effectiveness in reducing several water quality parameters. Table 5 and Figure 5 shows that the SPAM 2's WTP reduced color by 25%, turbidity by 9%, Fe by 35%, and Mn by 25%. Filtration media configurations such as zeolite, sand, coconut husk, and gravel efficiently reduce turbidity and heavy metal concentrations, particularly manganese (Sulianto et al., 2020). Although it successfully reduced several physical and chemical parameters, the filtration method in the SPAM 2's WTP did not show significant results for microbiological parameters. Test results showed that *E. coli* increased by 57% after filtration, and total coliform remained in TNTC condition. This indicates that a passive

filtration system without disinfection processes, such as chlorination or ultraviolet light, is ineffective in inactivating pathogenic microorganisms. Additionally, the SPAM 2's WTP did not effectively reduce the TDS concentration. TDS levels after filtration tended to remain the same or slightly increase. This may occur because TDS consist of tiny dissolved ions that cannot be effectively filtered by physical media such as sand and gravel. Furthermore, nitrite and nitrate levels increased by 10% each after filtration. This increase may stem from decomposing organic compounds in the filter media that are not routinely cleaned or ongoing biological contamination within the filtration system.

The differences in water treatment technology applied at the SPAM 1 and SPAM 2's WTPs significantly impacted the ability to remove various water quality parameters. Overall, the results of this study indicate that the combination of Carbon Sand Filter and UV at SPAM 1 is more effective in addressing microbiological contaminants and specific chemical parameters. At the same time, conventional filtration at SPAM 2 is more effective in reducing turbidity. However, TDS, manganese, and microbiological parameters still exceeded standards at the household level.

The findings highlight the significance of household-level interventions in safeguarding public health. Point-of-use (PoU) technologies, including household filtration units and chlorination systems, are recommended to enhance drinking water safety.

CONCLUSIONS

Based on the results of water quality testing at six sampling points in each of the RDWSS Tirta Wening (SPAM 1 and SPAM 2) networks, it can be concluded that most physical parameters such as temperature, turbidity, color, and odor meet the quality standards in the Regulation of the Indonesian Ministry of Health No. 3 of 2023. This finding is in line with customer perceptions, who generally rate the physical quality of the water as good. However, the TDS parameter shows concentration exceeding the quality standards at several sampling points. For chemical parameters such as nitrite, nitrate, and iron, all sampling points in both networks remain within safe limits. The pH parameter generally meets the quality standards, except

at the source of backup water in SPAM 2, of which the value is below the established quality standards. Manganese concentrations exceed the quality standards at one point in SPAM 1 and three points in SPAM 2. For microbiological parameters, *E. coli* levels in SPAM 1 indicate that four out of six sampling points exceed the quality standards, while all sampling points in SPAM 2 network show *E. coli* levels above the quality standards. total coliform levels also show that all sampling points in the SPAM 1 and SPAM 2 networks exceeded the established quality standards.

Based on the comparison of water treatment plant performance, the SPAM 1's WTP, which uses carbon sand filter and ultraviolet light technology, was proven more effective in reducing microbiological content such as *E. coli* and total coliform, with removal efficiency reaching 100%. Additionally, the SPAM 1's WTP effectively reduces levels of several chemical parameters, such as iron by 100%, nitrite by 64%, nitrate by 21%, and manganese by 50%. On the other hand, the SPAM 2's WTP, which employs filtration using coconut fiber, gravel, and sand filters, performs better in reducing turbidity, with an efficiency of 9%. Although SPAM 1 has used water treatment technologies such as carbon sand filters and ultraviolet light, the water quality received by customers is still not optimal. Water quality at the household level did not differ significantly between SPAM 1 and SPAM 2, suggesting that additional interventions at the household level are needed.

SUGGESTIONS

Further research is needed to address the lack of monitoring frequency of the water quality in Tirta Wening RDWSS against seasonal variations. In addition, it is important to increase the number of sampling points along the distribution network. The PoU system-based technology at the household level should also be considered as an additional solution to improve the quality of drinking water consumed by the community.

REFERENCES

- Adedotun, S. B., Adedotun, D. O., Ogundahun, D. S., Ibrahim, R. B., Olayode, O., & Ewedairo, S. K. (2024). *Assessment of Water Supply and Water Quality in the Rural Area of Obokun Local Government*. [\[Crossref\]](#) [\[Publisher\]](#)
- Adjovu, G. E., Stephen, H., James, D., & Ahmad, S. (2023). Measurement of Total Dissolved Solids and Total Suspended Solids in Water Systems: A Review of the Issues, Conventional, and Remote Sensing Techniques. *Remote Sensing*, 15(14), 3534. [\[Crossref\]](#) [\[Publisher\]](#)
- Alhoshy, M. A., Samhan, F. A., El-Gendy, A. S., & Razeq, T. M. A. (2025). Impact of Biofilm in Distribution Water Systems on Water Characteristics and Attempts for Treatment. *Water, Air, & Soil Pollution*, 236(7), 463. [\[Crossref\]](#) [\[Publisher\]](#)
- Amin, S., Kazama, S., Sawangjang, B., & Takizawa, S. (2024). Causes and Effects of Scale Deposition in Water Supply Pipelines in Surakarta City, Indonesia. *Water*, 16(16), 2275. [\[Crossref\]](#) [\[Publisher\]](#)
- Anifah, E., Ariani, I. K., Tindaon, J. T. P., & Basransyah. (2024). Adsorption of iron and manganese from acid mine drainage by zalacca (*Salacca zalacca*) peel-activated carbon. *Sustinere: Journal of Environment and Sustainability*, 8(1), 44–53. [\[Crossref\]](#) [\[Publisher\]](#)
- Barid, B., Galihajiningtresna, W. N., Nursetiawan, N., Hairani, A., & Hanacendekia, S. (2025). Sebaran Kualitas Air Bersih Sepanjang Jaringan Pipa SPAMDes Tirta Sari Ponces, Kulon Progo. *Teras Jurnal: Jurnal Teknik Sipil*, 15(1), 213–224. [\[Crossref\]](#) [\[Publisher\]](#)
- Bolatova, Z., Sharapatova, R., Kanagat, K., Kabiye, Y., Berndtsson, R., & Tussupova, K. (2025). Household Satisfaction and Drinking Water Quality in Rural Areas: A Comparison with Official Access Data. *Sustainability*, 17(15), 7107. [\[Crossref\]](#) [\[Publisher\]](#)
- Domoń, A., Kowalska, B., Papciak, D., & Wojtas, E. (2025). Assessment of the stability of tap water in the distribution system. *Desalination and Water Treatment*, 322, 101130. [\[Crossref\]](#) [\[Publisher\]](#)
- Duran-Ros, M., Pujol, J., Pujol, T., Cufí, S., Graciano-Urbe, J., Arbat, G., Cartagena, F., & Puig-Bargués, J. (2024). Efficiency of Backwashing in Removing Solids from Sand Media Filters for Drip Irrigation Systems. *Agriculture*, 14(9). [\[Crossref\]](#) [\[Publisher\]](#)
- Elewa, A. M., Amer, A. A., Attallah, M. F., Gad, H. A., Al-Ahmed, Z. A. M., & Ahmed, I. A. (2023). Chemically Activated Carbon Based on Biomass for Adsorption of Fe(III) and Mn(II). *Ions from Aqueous Solution. Materials*, 16(3), 1251. [\[Crossref\]](#) [\[Publisher\]](#)
- Haider, H., Alkhowaiter, M. H., Shafiquzzaman, M. D., Alresheedi, M., AlSaleem, S. S., & Ghumman, A. R. (2021). Source to Tap Risk Assessment for Intermittent Water Supply Systems in Arid Regions: An Integrated FTA—Fuzzy FMEA Methodology. *Environmental Management*, 67(2), 324–341. [\[Crossref\]](#) [\[Publisher\]](#)
- Hamidah, W., & Cindramawa, C. (2020). Analisis Kadar pH, Total Dissolved Solid (TDS) dan Mn pada Air Sumur Gali di Kabupaten Cirebon. *INDONESIAN JOURNAL OF CHEMICAL RESEARCH*, 5(1), 8–15. [\[Crossref\]](#) [\[Publisher\]](#)
- Hassan, I., Salamah, S. K., & Bob, M. (2025). Comprehensive Evaluation of Drinking Water Quality and the Effect of the Distribution Network in Madinah City, Saudi Arabia. *Water*, 17(18), 2711. [\[Crossref\]](#) [\[Publisher\]](#)
- Huang, Y., Yang, J., Liu, C., Jing, R., & Lu, Q. (2024). Spatial and Temporal Variations in Rainwater Chemistry in a Rapid Urbanization Area of Shenzhen, China. *Atmosphere*, 15(12), 1536. [\[Crossref\]](#) [\[Publisher\]](#)
- Khalid, B., & Alodah, A. (2023). Multivariate Analysis of Harvested Rainwater Quality Utilizing Sustainable Solar-Energy-Driven Water Treatment. *Sustainability*, 15(19), 14568. [\[Crossref\]](#) [\[Publisher\]](#)
- Lahay, I. H., Wolok, E., Dako, R. D. R., & Umara, A. M. (2024). Peningkatan Kesejahteraan Masyarakat Desa Masuru melalui Pengelolaan Sumber Daya Alam dan Infrastruktur yang Berkelanjutan. *Jurnal Pengabdian*

- Teknik Industri*, 3(2), 39–45. [[Crossref](#)] [[Publisher](#)]
- Lahlou, Z. M. (2018). Point-of-Use/Point-of-Entry systems for water quality compliance. *National Drinking Water Clearinghouse*. [[Publisher](#)]
- Nawiswary, A. A., & Tangahu, B. V. (2023). Desain Media Filter Pasir Silika dan Filter Karbon Aktif sebagai Teknologi Pengolahan Air Tanah Tercemar di Sekitar Lahan Bekas TPA Keputih. *Jurnal Purifikasi*, 21(1), 1–10. [[Crossref](#)] [[Publisher](#)]
- Nazar, Z. O., & Al-Musawi, N. O. A. (2021). Performance application of ultraviolet disinfection technique for raw water. *Journal of Physics: Conference Series*, 1895(1), 12036. [[Crossref](#)] [[Publisher](#)]
- Nowicki, S., Koehler, J., & Charles, K. J. (2020). Including water quality monitoring in rural water services: why safe water requires challenging the quantity versus quality dichotomy. *Npj Clean Water*, 3(1), 14. [[Crossref](#)] [[Publisher](#)]
- Odhiambo, M., Viñas, V., Sokolova, E., & Pettersson, T. J. R. (2023). Health risks due to intrusion into the drinking water distribution network: hydraulic modelling and quantitative microbial risk assessment. *Environmental Science: Water Research & Technology*, 9(6), 1701–1716. [[Crossref](#)] [[Publisher](#)]
- Propolsky, D., & Romanovski, V. (2025). Iron and manganese removal from groundwater: comprehensive review of filter media performance and pathways to polyfunctional applications. *Environmental Science: Water Research & Technology*, 11(11), 2499–2515. [[Crossref](#)] [[Publisher](#)]
- Shrestha, A. M., Kazama, S., Sawangjang, B., & Takizawa, S. (2024). Improvement of Removal Rates for Iron and Manganese in Groundwater Using Dual-Media Filters Filled with Manganese-Oxide-Coated Sand and Ceramic in Nepal. *Water*, 16(17), 2450. [[Crossref](#)] [[Publisher](#)]
- Sombeij, D. C., Mecha, C. A., & Chollom, M. N. (2025). A Review of Low-Cost Point-of-Use Water Treatment Solutions Addressing Water Access and Quality in Resource-Limited Settings. *Water*, 17(12), 1827. [[Crossref](#)] [[Publisher](#)]
- Stefan, D. S., Bosomoiu, M., & Teodorescu, G. (2023). The Behavior of Polymeric Pipes in Drinking Water Distribution System—Comparison with Other Pipe Materials. *Polymers*, 15(19), 3872. [[Crossref](#)] [[Publisher](#)]
- Sulianto, A. A., Aji, A. D. S., & Alkahi, M. F. (2020). Rancang Bangun Unit Filtrasi Air Tanah untuk Menurunkan Kekeuhan dan Kadar Mangan dengan Aliran Upflow. *Jurnal Sumberdaya Alam Dan Lingkungan*, 7(2), 72–80. [[Crossref](#)] [[Publisher](#)]
- Świetlik, J., & Magnucka, M. (2025). Aging of drinking water transmission pipes during long-term operation as a potential source of nano- and microplastics. *International Journal of Hygiene and Environmental Health*, 263, 114467. [[Crossref](#)] [[Publisher](#)]
- Vacs Renwick, D., Heinrich, A., Weisman, R., Arvanaghi, H., & Rotert, K. (2019). Potential Public Health Impacts of Deteriorating Distribution System Infrastructure. *Journal AWWA*, 111(2), 42–53. [[Crossref](#)] [[Publisher](#)]
- Wu, J., Cao, M., Tong, D., Finkelstein, Z., & Hoek, E. M. V. (2021). A critical review of point-of-use drinking water treatment in the United States. *NPJ Clean Water Clean Water*, 4(1), 40. [[Crossref](#)] [[Publisher](#)]
- Zhou, Q., Bian, Z., Yang, D., & Fu, L. (2023). Stability of Drinking Water Distribution Systems and Control of Disinfection By-Products. *Toxics*, 11(7), 606. [[Crossref](#)] [[Publisher](#)]
- Zikrina, M. N., Kazama, S., Sawangjang, B., & Takizawa, S. (2024). Filling Discrepancies between Consumer Perception and Actual Piped Water Quality to Promote the Potable Use of the Municipal Water Supply in Indonesia. *Sustainability*, 16(16), 7082. [[Crossref](#)] [[Publisher](#)]