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RESEARCH ARTICLE

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Seasonal Assessment of Water Quality and Pollution Index of Cileungsi River in Bogor Regency, Indonesia

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ABSTRACT

The Cileungsi River is the upstream part of the Bekasi Watershed, and its existence is crucial for the sustainability of the local economy and the survival of the community, industry, agriculture, and commerce surrounding the riverbanks. It is also the raw water source for Regional Water Company. This study aims to assess the water quality of the Cileungsi River and its pollution status using the Pollution Index (PI) method. This research was conducted at six sampling points, covering the upstream, middle, and downstream sections in both the dry and rainy seasons of 2022. The method used to analyze the water quality of the Cileungsi River refers to the Indonesian National Standard. In contrast, the calculation of the PI refers to the Decree of the State Minister of Environment. During the dry season, the PI at the Regional Water Company bridge in Kota Wisata and beside *PT Rahayu Indah Kulit* fell into the moderately polluted category, with PI values of 5.49 and 7.30, respectively. The highest PI value during the rainy season was recorded at 10.30 on the border of Bogor Regency and Bekasi City, which falls within the heavily polluted category. The *Gunung Putri* area has a lightly polluted index value in both seasons. The parameters that require attention are BOD, NO_2^-, free chlorine, and fecal coliform, which serve as indicators of pollution from household and agricultural activities. These results will help the Bogor Regency government develop strategies to protect and sustainably manage the Cileungsi River.

Introduction

Rivers are important ecological components that support human life and other living organisms. Rivers serve as a primary source of water, providing essential resources such as food, materials, and transportation. Therefore, rivers play an essential role in trade and economic growth [1]. The decline in water quality is one of the issues addressed by this current reality and can adversely affect human health. Generally, water pollution comes from anthropogenic sources, such as domestic and industrial waste, population growth, the use of pesticides and fertilizers, organic and non-organic waste, and weak water resource management systems [2]. Rapid population growth and urbanization can pressure ecosystems and aquatic environments, such as rivers, and affect river water quality [3].

The Cileungsi River is one of the waterways in the regulatory area of Bogor Regency, West Java, which flows from south to north and merges with the Cikeas River to form the Bekasi River, which then discharges into the Northern Shore of Java [4]. The Cileungsi River crosses seven sub-districts: Gunung Putri, Klapanunggal, Cileungsi, Bantargebang, Jati Asih, Mustikajaya, and Rawa Lumbu. According to data from the Central Bureau of Statistics of Bogor Regency, the population of Bogor Regency in 2022 was 5,566,838 people. Population growth and urbanization in Bogor Regency are occurring at a faster rate than in other cities in Indonesia. As

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of 2022, the population in Bogor Regency is the largest in West Java Province, accounting for 11.25 percent of the total population. This population growth has spurred various developments, including housing and industrial projects [5]. Effendi et al. [6] stated that the Cileungsi River has been polluted, with the primary source of pollution originating from industrial waste.

Contaminants that enter the Cileungsi River are likely to originate from synthetic organic materials, inorganic materials, and several metals that are industrial pollutants. Sulandari et al. [7] focused on the Cileungsi River water quality monitoring report made online using the Onlimo (Online Monitoring) telemetry system and found that the water in the Cileungsi River contains ammonia 14.2%, BODn5.5%, COD 1.6%, DOn0.4%, Nitrate 0.2%, PHm0.01%, TDSm0.1%, and TSS 1.11%. This indicates that the water quality of the Cileungsi River is in the category of severe pollution. To date, Pratiwi et al. [8] conducted research to determine the water quality status of the Cileungsi River in the upstream section, whereas Effendi et al. [6] conducted research only in the middle and downstream sections. The novelty of this study lies in determining the water quality status of the Cileungsi River at various points, including upstream, middle, and downstream, during both the dry and rainy seasons.

Water quality inspection of the Cileungsi River must be conducted continuously to determine the water capacity of the manager. Therefore, an index can be used to determine the level of pollution relative to the permitted water quality parameters. The PI is a method used to assess water quality status in Indonesia. Many researchers use the PI to determine a body's quality status because this method greatly reduces the amount of data and makes it easier to communicate the state of water quality [9]. According to Yusnita and Triajie [10], the use of the PI method is easier than other methods, more efficient, and faster in making conclusions. In addition, other researchers stated that the PI method has very detailed calculations to determine water quality [11] and can be used only based on a single data point [12]. This study aimed to evaluate the current water quality of the Cileungsi River using the PI technique. Its goal is to provide input to decision-makers so that they can assess the quality of water bodies and take action to improve the quality if it decreases owing to the presence of pollutant compounds.

Materials and Methods

Study Area

Data on the water quality of the Cileungsi River were collected through observational data by BBWS CC (*Balai Besar Wilayah Sungai Ciliwung Cisadane*) and DLH (*Dinas Lingkungan Hidup*), Bekasi City. This study evaluates river water quality over one year in 2022. Water quality monitoring by BBWS CC is carried out four times a year, namely in February and May (dry season) and August and November (rainy season), while the Bekasi City Environment Agency monitors river water quality three times a year, namely in March (dry season) and July and October (rainy season). River water monitoring data were obtained from laboratory test results at six sampling points (SP) in the Cileungsi River waters, and a description of the sampling points is shown in Table 1.

Table 1. Description of the six sampling points in the Cileungsi River.

Sample site	Brief description
SP1	Upper Stream (Regional Water Company Bridge of Kota Wisata)
SP2	In the Gunung Putri area, where the river is polluted with domestic waste, runoff, etc.
SP3	At the border of Bogor Regency and Bekasi City, where the river is polluted with domestic waste, runoff, etc.
SP4	The site at which effluents released from PT Millenium Laundry join the Cileungsi River
SP5	The site at which effluents released from PT Rahayu Indah Kulit join the Cileungsi River
SP6	The site downstream is where effluents released from PT Asmar Nakatama Partogi join the Cileungsi River.

Field sampling began in the morning and lasted until afternoon. Likewise, the measurement of river water temperature directly follows the sampling time; therefore, the measured water temperature is influenced by the ambient temperature during the sampling process. The sampling technique employed in this work is based on the scope, where river water quality sampling is conducted at specified times. For each location, composite sampling was conducted (mixing locations on both banks of the river and the middle, according to

SNI 8995:2021 which regulates the method of taking water test samples for physical and chemical testing). The volume of samples collected for field and laboratory examinations depends on the type of examination. To examine the physical and chemical properties of water, approximately 3 liters were required. The specified sampling point encompasses the entire length of the Cileungsi River, from upstream to downstream, with SP1 located upstream and SP6 located downstream.

All sampling points were selected based on potential activities or activities that have the potential to pollute river waters, such as industrial and residential activities. The observed parameters are divided into three types, namely physical, chemical and biological parameters. Physical parameters observed were temperature, total dissolved solids (TDS), total suspended solids (TSS). Chemical parameters observed were pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), chloride (Cl-), nitrate-N, nitrite-N, ammonia-N, total phosphate, fluoride (F^-), free chlorine, dissolved cobalt (Co), dissolved nickel (Ni), dissolved zinc (Zn), and dissolved copper (Cu). The biological parameters observed were only fecal coliforms in this study. The parameter measurements were divided into two conditions: in situ measurements and laboratory tests. In situ samples were collected using direct measurement. The pH and temperature of the samples were measured directly, whereas the other parameters were measured using laboratory tests. Figure 1 shows a map of the six sampling points in the Cileungsi River.

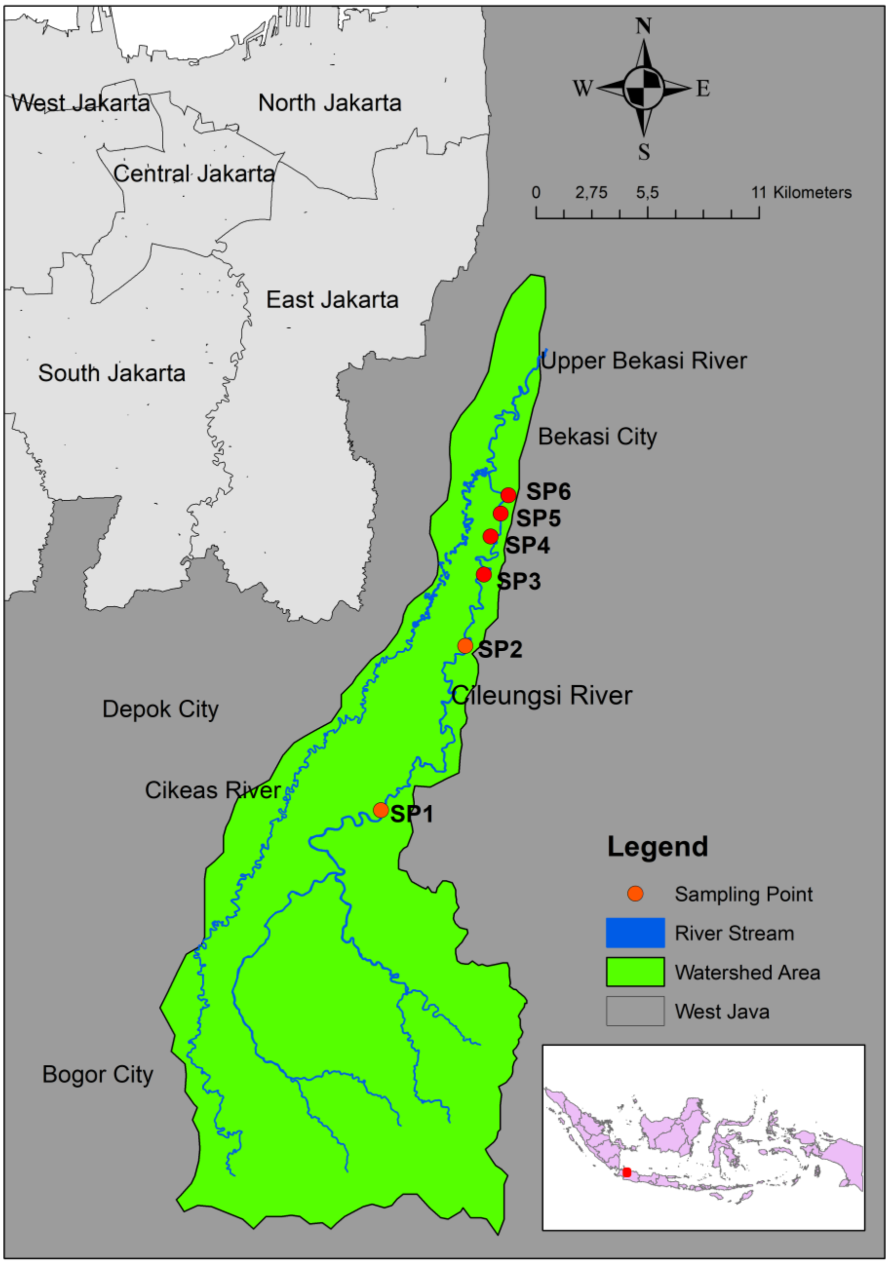

Figure 1. Six sampling points were collected from the Cileungsi River in West Java Province, Indonesia.

The methods used to analyze various physical, chemical, and biological parameters of river water were adopted from *Standar Nasional Indonesia* (SNI) and the American Public Health Association (APHA). This study used 19 parameters to assess the quality of river water. Table 2 describes the analysis method for all the water quality parameters of the Cileungsi River. Descriptive methods are used to describe the level of pollution in the Cileungsi River.

Table 2. Water quality parameters and types of analysis methods employed.

Parameter	Unit	Class II standards	Methods adopted
Temperature	ºC	± 3	EC Meter
Total Dissolved Solid (TDS)	mg/L	1,000	Gravimetric Method
Total Suspended Solid (TSS)	mg/L	50	Gravimetric Method
pH		6–9	Electrometric
Biochemical Oxygen Demand (BOD)	mg/L	3	Titrimetric
Chemical Oxygen Demand (COD)	mg/L	25	Titrimetric
Dissolved Oxygen (DO)	mg/L	4	Titrimetric
Chloride (Cl-)	mg/L	300	Argentometric
Nitrate-Nitrogen	mg/L	10	Spectro Direct Lovibond at wavelength 543 nm
Nitrite-Nitrogen	mg/L	0.06	Spectro Direct Lovibond at wavelength 545 nm
Ammonia-Nitrogen	mg/L	0.2	Spectrophotometric at wavelength 640 nm
Phospate Total	mg/L	0.2	Spectrophotometric at wavelength 880 nm
Fluoride (F-)	mg/L	1.5	Spectrophotometric at wavelength 570 nm
Free chlorine	mg/L	0.03	Spectro Direct Lovibond at wavelength 510 nm
Dissolved Cobalt (Co)	mg/L	0.2	AAS at wavelength 240.7 nm
Dissolved Nickel (Ni)	mg/L	0.05	AAS at wavelength 232.0 nm
Dissolved Zinc (Zn)	mg/L	0.05	AAS at wavelength 213.9 nm
Dissolved Copper (Cu)	mg/L	0.02	AAS at wavelength 324.7 nm
Fecal Coliform	MPN/100mL	1,000	Most Probable Number (MPN)

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

The PI technique was used to assess the water quality of the Cileungsi River, in accordance with the Decree of the State Minister of Environment No. 115 of 2003, which outlines guidelines for determining water quality status. The pollution index determines the level of contamination in relation to acceptable water quality standards. This method can contribute to the assessment of the nature of a water body for a specific assignment, as well as make a move to develop water quality further if there is a declining quality due to contaminating mixtures [13]. Based on the Governor of West Java Regulation Number 12 of 2013 Concerning Water Quality Standards and Water Pollution Control, Cimanuk River, Cilamayan River, and Bekasin River, then water quality classification in the waters of the Cileungsi River is assigned to class II. Class II river water quality standards mean water that can be used for water recreation, infrastructure, facilities, freshwater fish farming, water for irrigating crops, and/or other uses that require the same water quality as these uses.

The PI calculation compares river water quality monitoring data with class I river water quality standards, as outlined in Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (Appendix VI). To determine the quality status, it was necessary to calculate the C_i/L_{ij} value for each parameter at each sampling location using several formulas. If the parameter concentration value decreases, it indicates that the level of pollution increases; first, determine the theoretical value or maximum value of C_{im} (e.g., for DO, then C_{im} is the saturated DO value). In this case, the C_i/L_{ij} value in the measurement results is replaced with the C_i/L_{ij} value stated in equation (1). If the standardized value (L_{ij}) does not have a range, then use the calculation in equation (2). If the (L_{ij}) value is within the smaller C_i range equal to the average L_{ij} then use the calculation in equation (3). However, if the value of (L_{ij}) is in the range C_i, which is greater than the average L_{ij} then the calculation in equation (4) is used. If the value of (C_i/L_{ij}) is smaller than 1.0 then the calculation in equation (2) is used. If the value of (C_i/L_{ij}) is greater than 1.0 with a value of P then the calculation in equation (5) is used. The average value of all data is expressed as $(C_i/L_{ij})_R$, while the maximum value as $(C_i/L_{ij})_M$. The PI_j value is expressed by the calculation in equation (6).

$$C_{ij}/L_{ij} = \frac{C_{im} - C_{i\ the\ measurement\ result}}{C_i - L_{ij}} \tag{1}$$

$$C_{ij}/L_{ij} = C_i/L_{ij\ the\ measurement\ result} \tag{2}$$

$$C_{ij}/L_{ij} = \frac{C_i - L_{ij\ average}}{L_{ij\ minimum} - L_{ij\ average}} \tag{3}$$

$$C_{ij}/L_{ij} = \frac{C_i - L_{ij\ average}}{L_{ij\ maximum} - L_{ij\ average}} \tag{4}$$

$$C_{ij}/L_{ij\ new} = 1.0 + P\ Log\ (C_i/L_{ij})_M \tag{5}$$

$$PI_j = \frac{\sqrt{(C_i/L_{ij})_M{}^2 - (C_i/L_{ij})_R{}^2}}{2} \tag{6}$$

L_{ij}. : The concentration of water quality in the standard base of regulation (j)
C_i. : The concentration of water quality measurement
PI_j. : Pollution index (j)
$(C_i/L_{ij})_M$. : The maximum value of C_i/L_{ij}
$(C_i/L_{ij})_R$. : The average value of C_i/L_{ij}

The results of the pollution index calculation are used to determine the water quality status of a body of water (Table 3). A few specialists have used the PI technique to evaluate river water quality [2,6,7]. The pollution index value in Table 3 lacks units; however, the value PI = 1.0 is a critical value, as it is expected to be met as a quality standard for water use. The greater the PI value, the greater the level of pollution of the water body. The definition of quality standards, as outlined in Government Regulation Number 22 of 2021, measures the limits of living things, substances, energies, or components that are present or must be present, and/or pollutant elements whose presence is tolerated in water.

Table 3. Pollution index values and water quality status categories in water bodies.

Pollution index (PI) values	Water quality
0–1.0	Good/meets standard
1.0–5.0	Lightly polluted
5.0–10.0	Moderately polluted
> 10	Heavily polluted

Results and Discussion

Results

Measurement of Temperature, TDS, TSS, and pH Parameters

Water quality measurements of the Cileungsi River were conducted at six sampling points during both the rainy and dry seasons. The dry season in Indonesia typically spans from January to June, while the rainy season generally occurs from July to December. Data on the temperature, TDS, TSS, and pH measurements are shown in Table 4. The concentration of the four parameters at each sampling point fluctuated greatly. The water quality of the Cileungsi River also varies by season. The trend in the results of monitoring the water quality of the Cileungsi River indicates that the concentrations of TDS and TSS are higher during the rainy season than during the dry season. The trend in temperature and pH parameters did not show any significant changes in the two seasons. Water quality at all points meets the class standards for the river water quality parameters set for temperature, TDS, and pH. However, the TSS parameter at all points has exceeded the river water standard.

Table 4. Temperature, TDS, TSS, and pH values at six sampling points in milligrams/liter (mg/L).

Sample site	Season	Month	Temperature (°C)	TDS (mg/L)	TSS (mg/L)	pH
SP1	Dry season	Feb	26.6	221.0	104.0	6.60
		May	26.6	221.0	104.0	6.60
	Rainy season	Aug	28.5	357.0	40.0	6.60
		Nov	29.6	210.0	47.0	6.80

Sample site	Season	Month	Temperature (°C)	TDS (mg/L)	TSS (mg/L)	pH
SP2	Dry season	Feb	28.3	232.0	31.0	7.70
		May	28.2	199.0	90.0	7.00
	Rainy season	Aug	29.7	232.0	17.0	7.40
		Nov	29.4	186.0	68.0	6.60
SP3	Dry season	Mar	28.9	206.0	33.0	7.30
	Rainy season	Jul	27.0	268.0	10.0	7.38
		Oct	28.0	172.0	929.0	6.82
SP4	Dry season	Mar	29.0	178.0	86.0	7.31
	Rainy season	Jul	29.0	128.0	12.0	7.12
		Oct	28.0	116.0	162.0	6.79
SP5	Dry season	Mar	30.0	264.0	54.7	7.19
	Rainy season	Jul	31.0	290.0	22.0	6.98
		Oct	28.0	138.0	140.0	6.88
SP6	Dry season	Mar	29.0	170.0	53.3	7.18
	Rainy season	Jul	31.0	248.0	24.0	6.87
		Oct	28.0	144.0	186.0	6.66
Class ii standard[a]			Deviation 3	1,000	50	6–9

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

Measurement of BOD, COD, DO, and Chloride Parameters

The biochemical aspect commonly tested and used to determine the level of water pollution is the amount of dissolved oxygen in water [14]. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are indicators of organic and inorganic pollution in water, causing a decrease in dissolved oxygen levels [15]. Data on BOD, COD, DO, and chloride test results are displayed in Table 5. There were concentration fluctuations for the four parameters at each sampling point. In addition, there was an increase in the concentrations of the four parameters during the rainy season. COD values are always higher than BOD because many organic substances can be oxidized chemically but not biologically [16]. The concentration of BOD and DO at all sampling points has exceeded the quality standards for class II river water. However, the chloride concentration meets the quality standards for all points. For COD parameters, only points SP2 and SP3 meet the quality standards.

Table 5. BOD, COD, DO, and chloride values in 2022 at six sampling points in milligrams/liter (mg/L).

Sample Site	Season	Month	BOD (mg/L)	COD (mg/L)	DO (mg/L)	Cl^- (mg/L)
SP1	Dry Season	Feb	8.40	28.00	2.00	17.200
		May	7.70	19.00	4.00	11.800
	Rainy Season	Aug	31.00	73.00	1.40	39.200
		Nov	35.00	66.00	3.00	14.500
SP2	Dry Season	Feb	6.30	12.00	5.00	11.000
		May	4.20	6.40	4.00	10.600
	Rainy Season	Aug	5.50	11.00	4.00	14.800
		Nov	6.30	13.00	3.00	12.800
SP3	Dry Season	Mar	3.26	24.04	2.77	9.430
	Rainy Season	Jul	4.73	16.24	2.54	27.880
		Oct	4.41	9.94	8.09	7.830
SP4	Dry Season	Mar	3.42	36.37	4.05	9.430
	Rainy Season	Jul	3.98	20.10	3.62	24.460
		Oct	3.00	20.13	8.17	8.080
SP5	Dry Season	Mar	4.20	34.68	3.81	9.430
	Rainy Season	Jul	5.10	13.44	3.54	24.460
		Oct	3.12	28.55	8.30	7.830
SP6	Dry Season	Mar	3.72	45.24	3.77	11.410
	Rainy Season	Jul	2.84	30.13	2.62	23.480
		Oct	2.18	14.87	8.40	7.830
Class II Standard[a]			3	25	4	300

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

Measurement of Nitrate, Nitrite, Ammonia, Total Phosphate, Florida, and Free Chlorine Parameters

The concentrations of nitrate, nitrite, ammonia, total phosphate, fluoride, and free chlorine during are shown in Table 6. The concentration of each parameter fluctuated significantly. The nitrate and fluoride concentrations at small sampling points were below the quality standards, while the other parameters had varying concentrations at each point.

Table 6. Values of nitrate, nitrite, ammonia, total phosphate, fluoride, and free chlorine at six sampling points in milligrams/liter (mg/L).

Sample Site	Season	Month	NO_3 (mg/L)	NO_2 (mg/L)	NH_3 (mg/L)	PO_4^{3-} Total (mg/L)	F^- (mg/L)	Free Cl^- (mg/L)
SP1	Dry Season	Feb	0.790	0.100	2.000	0.500	0.180	0.001
		May	0.680	0.060	0.200	0.700	0.180	0.001
	Rainy Season	Aug	0.064	0.020	2.000	0.500	0.078	0.001
		Nov	0.064	0.080	0.800	0.400	0.120	0.001
SP2	Dry Season	Feb	0.920	0.080	1.500	0.900	0.066	0.001
		May	0.920	0.050	0.070	0.700	0.150	0.001
	Rainy Season	Aug	0.950	0.200	0.080	0.800	0.170	0.001
		Nov	0.900	0.100	0.300	0.800	0.098	0.001
SP3	Dry Season	Mar	0.300	0.085	0.041	0.352	0.349	0.260
	Rainy Season	Jul	0.300	0.098	0.041	0.278	0.471	0.060
		Oct	0.300	0.028	0.041	0.184	0.416	0.660
SP4	Dry Season	Mar	1.000	0.086	0.041	0.194	1.460	0.130
	Rainy Season	Jul	0.300	0.130	0.062	0.233	0.458	0.690
		Oct	0.300	0.038	0.041	0.213	0.358	0.340
SP5	Dry Season	Mar	2.100	0.092	0.265	0.239	0.759	2.080
	Rainy Season	Jul	0.300	0.134	0.041	0.267	0.420	1.890
		Oct	0.300	0.050	0.041	0.182	0.696	0.240
SP6	Dry Season	Mar	0.900	0.093	0.041	0.242	1.190	0.260
	Rainy Season	Jul	0.300	0.117	0.041	0.240	0.473	0.110
		Oct	0.300	0.045	0.041	0.160	0.317	0.290
Class II Standard[a]			10	0.06	0.2	0.2	1.5	0.03

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

Measurement of Dissolved Cobalt, Dissolved Nickel, Dissolved Zinc, and Dissolved Copper Parameters

Heavy metals do not quickly decompose in nature and can accumulate in the bodies of humans and other organisms. Large amounts of heavy metals that accumulate in the body are highly toxic and can cause unwanted effects on the body. According to Paul [17], the effects of heavy metal ingestion in the body can lead to mental disorders, kidney damage, various types of cancer, and even death if exposed to very high amounts. Heavy metals are found in Cileungsi River water in the form of dissolved cobalt (Co), Nickel (Ni), Zinc (Zn), and Copper (Cu). The concentrations of the heavy metals in the dry and rainy seasons are listed in Table 7.

Table 7. Grades of dissolved cobalt, nickel, zinc, and copper at six sampling points in milligrams/liter (mg/L).

Sample Site	Season	Month	Co (mg/L)	Ni (mg/L)	Zn (mg/L)	Cu (mg/L)
SP1	Dry Season	Feb	0.0100	0.0700	0.0700	0.0700
		May	0.0100	0.0700	0.0300	0.0600
	Rainy Season	Aug	0.0100	0.0700	0.0300	0.0600
		Nov	0.0100	0.0700	0.0300	0.0600

Sample Site	Season	Month	Co (mg/L)	Ni (mg/L)	Zn (mg/L)	Cu (mg/L)
SP2	Dry Season	Feb	0.0100	0.0700	0.0700	0.0700
		May	0.0100	0.0700	0.0300	0.0600
	Rainy Season	Aug	0.0100	0.0700	0.0300	0.0600
		Nov	0.0100	0.0700	0.0300	0.0600
SP3	Dry Season	Mar	0.0263	0.0432	0.0221	0.0168
	Rainy Season	Jul	0.0263	0.0970	0.0221	0.0168
		Oct	0.0263	0.0432	0.0221	0.0168
SP4	Dry Season	Mar	0.0263	0.0432	0.0221	0.0168
	Rainy Season	Jul	0.0263	0.1050	0.0221	0.0168
		Oct	0.0263	0.0422	0.0221	0.0168
SP5	Dry Season	Mar	0.0263	0.0432	0.0221	0.0168
	Rainy Season	Jul	0.0263	0.1000	0.0221	0.0170
		Oct	0.0263	0.0432	0.0221	0.0168
SP6	Dry Season	Mar	0.0263	0.0432	0.0221	0.0168
	Rainy Season	Jul	0.0263	0.1220	0.0221	0.0180
		Oct	0.0263	0.0432	0.0320	0.0168
Class II Standard[a]			0.2	0.05	0.05	0.02

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

Measurement of Fecal Coliform Parameter

Fecal coliforms were detected in the Cileungsi River water, as shown in Table 8. The water quality at all sampling points contained fecal coliforms that exceeded the quality standards based on PP No.22 of 2021. The fecal coliform content at all sampling points fluctuates greatly, and it is not apparent how seasonal influences affect the increase in fecal coliform.

Table 8. Fecal coliform scores at six sampling points in most probable number (MPN)/100 milliliters (mL).

Sample site	Season	Month	Fecal coliform (MPN/100 mL)
SP1	Dry Season	Feb	20,000
		May	10,000
	Rainy Season	Aug	2,500
		Nov	3,090
SP2	Dry Season	Feb	15,260
		May	24,196
	Rainy Season	Aug	5,000
		Nov	2,950
SP3	Dry Season	Mar	7,280
	Rainy Season	Jul	24,196
		Oct	483,920
SP4	Dry Season	Mar	5,545
	Rainy Season	Jul	24,196
		Oct	6,700
SP5	Dry Season	Mar	3,090
	Rainy Season	Jul	19,863
		Oct	92,080
SP6	Dry Season	Mar	2,950
	Rainy Season	Jul	24,196
		Oct	70,685
Class II Standard[a]			1,000

[a]Class II Standard based on Indonesian Government Regulation No. 22 of 2021.

Water Pollution Index

One technique for assessing the state of water quality is PI. By comparing the predefined quality criteria, the water quality status indicates the circumstances of the source water. The water pollution index of the Cileungsi River in the dry and rainy seasons of 2022 is presented in Figure 2 and Figure 3. Based on the pollution index calculation, the results showed a decrease in the water quality of the Cileungsi River from upstream to downstream. The pollution index value from upstream to downstream tended to increase despite fluctuations at some sampling points. These fluctuations indicate that the water quality of the Cileungsi River is related to land use and anthropogenic activities around the river.

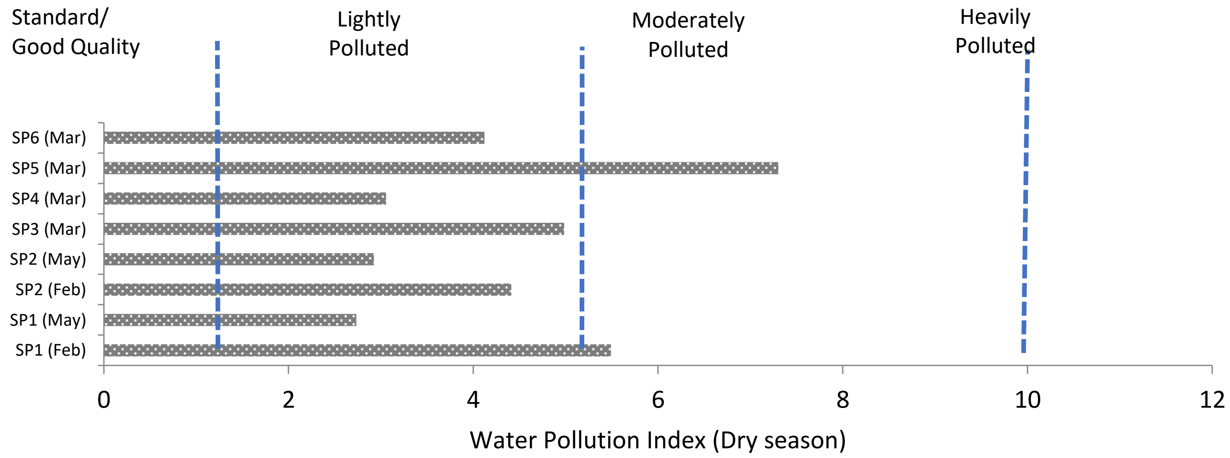

Figure 2. Water pollution index during the dry season 2022 on the Cileungsi River.

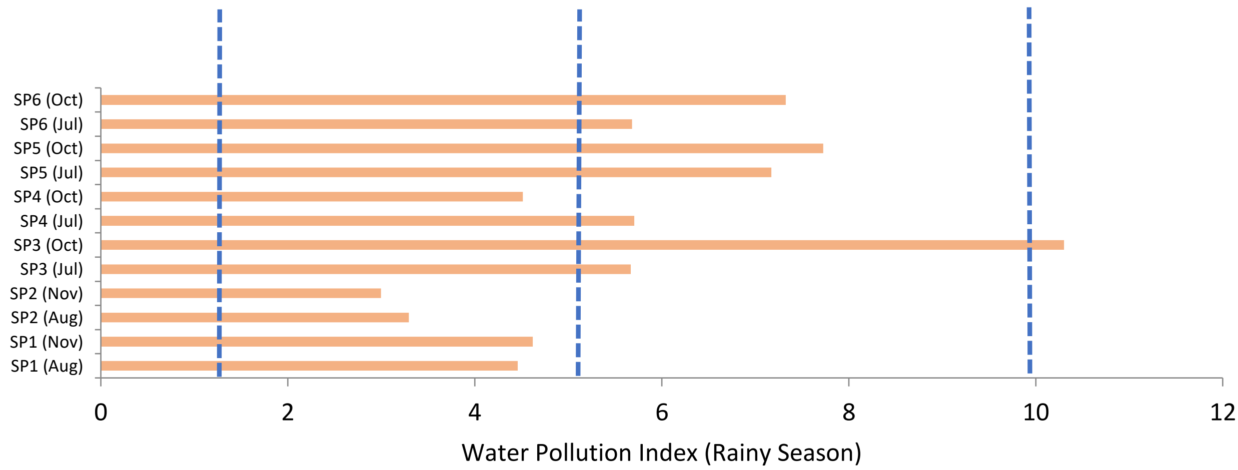

Figure 3. Water pollution index in rainy season 2022 of the Cileungsi River.

Discussion

Physical, Chemical, and Biological Trends in Cileungsi River

The water temperature of the Cileungsi River is 26.6–29.6 °C (dry season) and 27.0–31.0 °C (rainy season). This data aligns with the research conducted by Pratiwi et al. [8], who found that the average temperature of the Cileungsi River water in 2015–2019 was 29°C. Based on the results of daily rainfall monitoring by BBWS CC, it is known that July 2022 had the fewest rainy days compared to other months; therefore, river water temperatures in July were higher than in other months in 2022. Thus, even though the rainy season has begun in West Java, the intensity of sunlight remains very high, and rainfall is still low at the start of the season. Industrial waste discharge, weather, and climate factors can cause changes in the temperature of river water.

The TDS concentration in the Cileungsi River water was obtained at 170–264 mg/L (dry season) and 116–357 mg/L (rainy season), so that the water quality is still below class II river water quality norm of 1,000 mg/L. The essential wellsprings of TDS in the river are overflows from horticulture, homegrown, and modern waste [18]. The concentration obtained during the dry season is 31–104 mg/L, and the rainy season is 10–929 mg/L. The quality of river water at most sampling points exceeds the class II river water quality norm of 50 mg/L. The high concentration of TSS in the Cileungsi River was caused by the entry of industrial pollutants in the form of inorganic materials, synthetic organic materials, and several metals into the river.

In addition, the increase in TSS was also caused by excavation and land-clearing activities during mining exercises in the upper reaches of the Cileungsi River [19]. In mid-2022, construction activities began for the Living World Mall, the largest mall in East Jakarta and Bogor. The mall occupies an area of 6 ha with a building area of 200,000 square meters in the Kota Wisata Cibubur housing complex, bringing materials into the Cileungsi River and increasing TSS. High concentrations of TDS and TSS in water bodies can result in many negative impacts, such as the proliferation of harmful blue-green algae, accelerated eutrophication, and extreme turbidity, which negatively impact the depletion of limited water resources [20]. A graph comparing TSS concentrations with river water quality standards is shown in Figure 4.

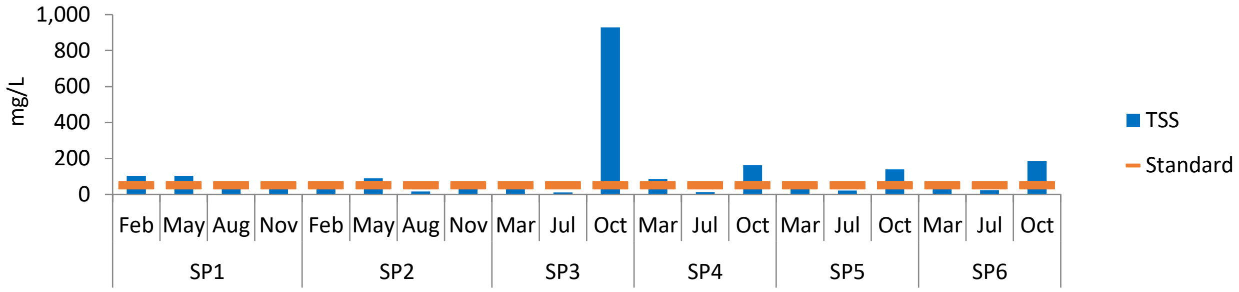

Figure 4. Comparison of TSS values and quality standards (mg/L).

The acidity or pH level of the Cileungsi River water ranges from 6.60 to 7.70 (dry season) and 6.60 to 7.40 (rainy season). When compared with Class II river water quality guidelines, the pH of river water meets the quality standards, namely at pH 6–9, so river water assignment can be utilized for water diversion offices, freshwater fish cultivation, creature farming, water to inundate crops, or potentially different assignments that require similar water quality for these purposes (PP No. 22 of 2021). Additionally, river water with a pH value of 6.50–7.50 is considered regular water that supports life [21]. The concentrations of BOD in the dry and rainy seasons were obtained at 3.26–8.40 mg/L and 2.18–35.00 mg/L, respectively. The highest grouping of BOD was found in SP1, located on the Regional Water Company bridge in Kota Wisata Cibubur. Compared to the Class II River water quality standard of 3 mg/L, almost all sampling points exceeded the quality standard, with only SP6 in July meeting the standard. High BOD levels in river water cause a higher oxygen intake to break down organic matter. This process decreases dissolved oxygen concentration in the air, resulting in an anoxic state in river water, which is harmful to aquatic organisms [22]. The comparison of BOD concentration with class II river water quality standards is shown in Figure 5.

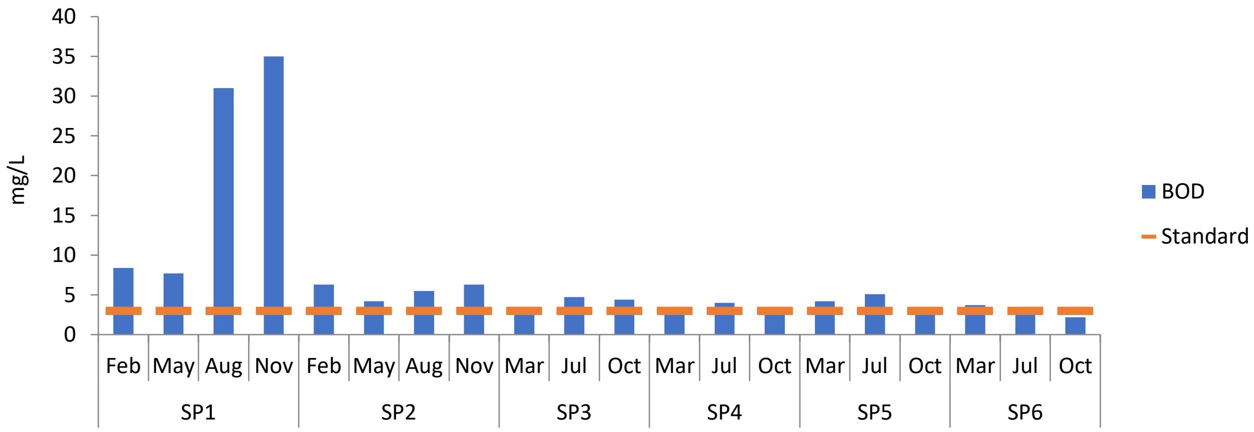

Figure 5. Comparison of BOD values and quality standards (mg/L).

COD concentration during the dry season ranged from 6.40 to 45.24 mg/L, and during the rainy season, it ranged from 9.94 to 73.00 mg/L; the greater the COD concentration, the more polluted the water. The COD parameter class II river water quality standard is 25 mg/L; therefore, in the dry season, only SP2 meets the quality standards of two measurements (February and May), whereas, in the rainy monsoon, SP1 and SP6 do not meet the quality standards, both in the first and second measurements. A comparison of COD concentrations to class II river water quality standards is shown in Figure 6.

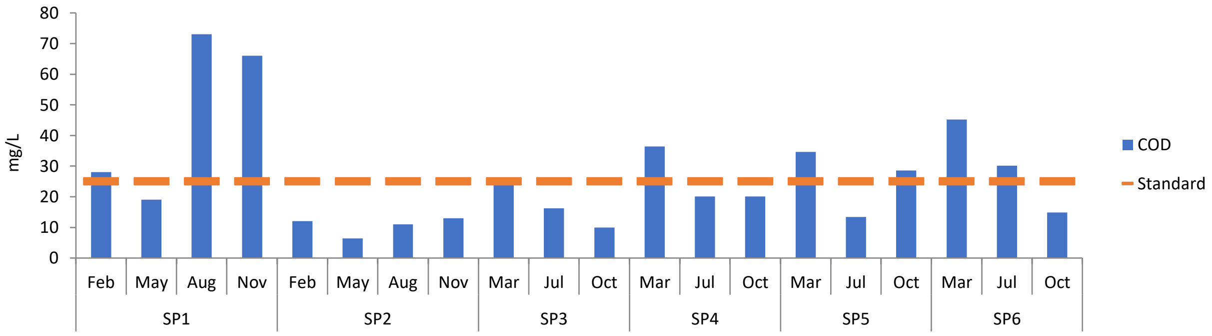

Figure 6. Comparison of COD values and quality standards (mg/L).

The high COD and BOD values in the rainy season compared to the dry season are attributed to the rainy season's relatively high intensity, which results in higher water discharge in the Cileungsi River. Therefore, many industrial waste outlet pipes are submerged in river water and used by many industries to dispose of their waste directly into water bodies. Similar to the BOD parameter, a high COD content in river water causes reduced oxygen levels, which can harm the biota in the river water [23]. The high COD values in the Cileungsi River water indicated high levels of organic pollutants. The decomposition of organic materials can cause an unpleasant or rotten odor, leading to respiratory problems for residents living near the Cileungsi River. DO is an essential parameter for the survival of all aquatic organisms [24]. The water quality of SP2 (February) and SP4 (March) met the standards during the dry season of 5.00 mg/L and 4.05 mg/L, where the Class II River water quality standard for DO parameters is at least 4 mg/L. During the rainy season, the river water samples SP3, SP4, SP5, and SP6, taken in October, meet the quality standards, with a range of 8.09 to 8.40 mg/L. The concentration of dissolved oxygen is influenced by water temperature and hydrometeorological conditions, as well as the forces of natural cycles, including respiration, photosynthesis, and the decomposition of natural matter, which cause frequent changes [25].

On average, the DO concentration was higher during the rainy season than during the dry season. Because in the rainy season, there is an increase in water flow into the river, which carries more dissolved oxygen into the river [26]. The chloride concentration in Cileungsi River water ranges from 9.43 to 17.2 mg/L (dry season) and 7.83 to 39.20 mg/L (rainy season), indicating that the quality of the river water at the sampling points meets the Class II river water quality standards of 300 mg/L. Mandal et al. [27] reported that the entry of chlorides into river waters comes from domestic and industrial wastewater discharge, fertilizer application, and urban and agricultural runoff water. The Cileungsi Sub-DAS area has a dense industrial area around the Cibinong cement factory, the Holcim cement factory, and the Branta-Mulia industrial area [28].

During dry and rainy seasons, the nitrate concentrations in the Cileungsi River water ranged from 0.300 to 2,100 mg/L and from 0.064 to 0.950 mg/L. The nitrate quality standard in river water is 10 mg/L; therefore, all sampling points met class II quality standards. Zhang et al. [29] stated that pollution hotspots, such as industrial and domestic wastewater, and the prominent use of fertilizers in agriculture, are causing increased nitrates in river water. Seasonal water temperature can also affect the increase and decrease in nitrate concentration in water; when the water temperature drops, the nitrate concentration also decreases [30]. Nitrite concentrations ranged from 0.050 to 0.100 mg/L (dry season) and 0.020 to 0.200 mg/L (rainy season), while nitrite quality standards in river water were 0.06 mg/L. Table 6 shows the river water that meets the quality standards during the dry season was only SP2 (May) of 0.050 mg/L, whereas, in the rainy season, the sampling points that met the quality standards were SP1 (August), SP3 (October), SP4 (October), SP5 (October), and SP6 (October), with consecutive values of 0.020, 0.028, 0.038, 0.050, and 0.045 mg/L. The nitrogen in nitrite is in a relatively unstable oxidized form, and nitrite has a high level of toxicity to living organisms that can cause methemoglobinemia, cyanosis, and asphyxia at higher concentrations [31].

Another test showed that the Cileungsi River water was contaminated with ammonia, with the highest concentration occurring in the dry season, and the rainy season is SP1 = 2,000 mg/L, where the quality standard set is 0.200 mg/L. Ammonia in water is tracked down in two species: ammonium ions and non-ionic ammonia. Ammonium ions are abundant in water with a neutral and alkaline pH, while non-ionic ammonia is a form of ammonia with a smaller amount than in water [32]. Both species are highly toxic to aquatic biota, and ammonia toxicity is influenced by temperature and pH. Phosphate test results during the dry season The concentrations ranged from 0.194 to 0.900 mg/L, and during the rainy season, they ranged from 0.160 to 0.800 mg/L.

The phosphate quality standard is 0.200 mg/L; therefore, in the dry season, only SP4 (March) meets the quality standard of 0.194 mg/L, whereas, in the rainy season, SP3, SP5, and SP6 in October were below the quality standard. Ammonia and phosphate are toxic metabolites because they contain nitrogen, which can stimulate algal growth (algal bloom) [33]. The natural entry of phosphate into a water body can be caused by rock weathering into phosphate minerals [34], agricultural waste in the form of phosphorus-based inorganic fertilizers [35], and the use of detergents by industry and communities in the waters [36]. River water containing ammonia and phosphate can also cause an unpleasant odor in the Cileungsi River. Ammonia has a sharp and pungent odor reminiscent of urine, whereas phosphate can trigger excessive algal growth, which rots and contributes to foam's unpleasant odor and appearance. This odor also disturbs residents around the Cileungsi River, making breathing more difficult.

The fluoride concentration in the river water at all sampling points was below the class II river water quality standard of 1.5 mg/L. Kitalika et al. [37] state that waters rich in fluoride concentrations are related to the origin of the sediments, i.e., mountainous and volcanic areas, granite, and gneissic rocks. Free chlorine was also found in the Cileungsi River water at 0.001–2,080 mg/L (dry season) and 0.001–1,890 mg/L (rainy season). The highest free chlorine concentration was found in SP5. During the rainy and dry seasons, at 2,080 and 1,890 mg/L, the class II river water quality standard is 0.03 mg/L. A comparison of the concentrations of nitrite, ammonia, and free chlorine against the class II river water quality standards is presented in Figure 7, Figure 8, and Figure 9.

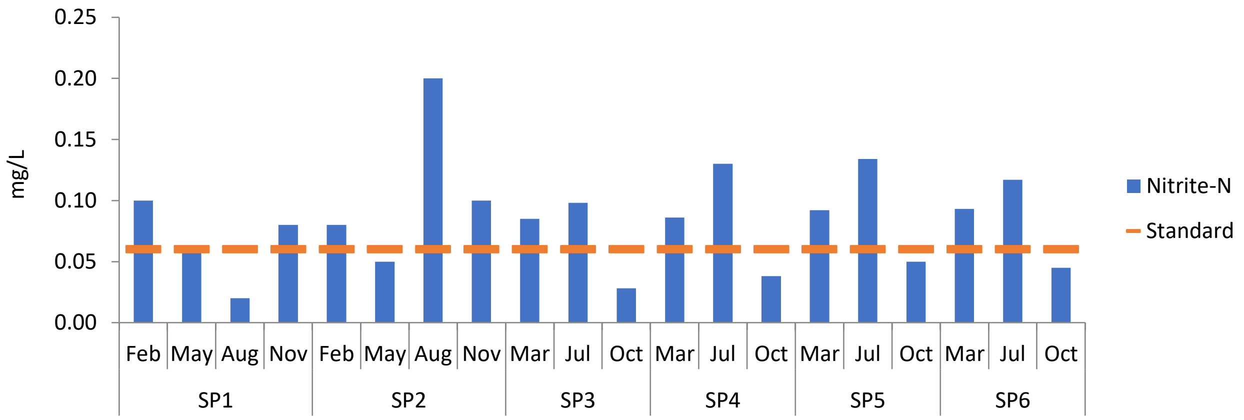

Figure 7. Comparison of nitrite values and quality standards in milligrams/liter (mg/L).

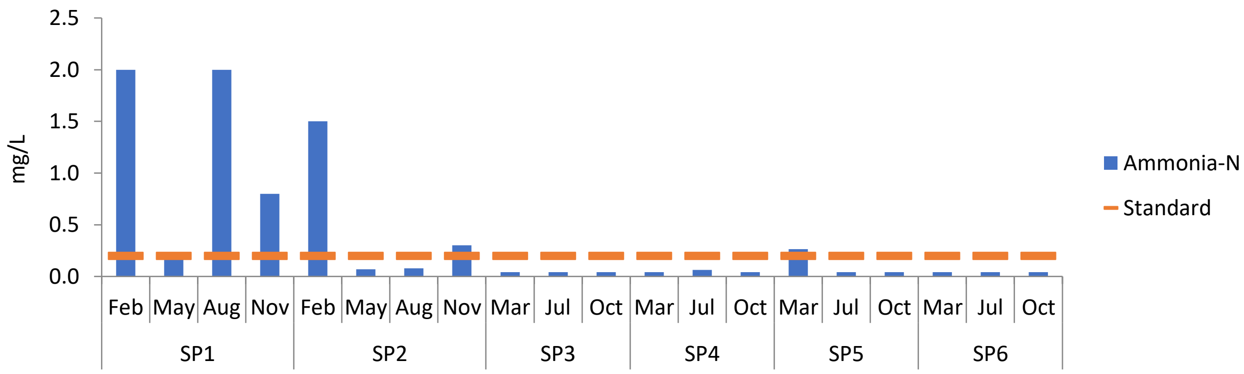

Figure 8. Comparison of ammonia values and quality standards in milligrams/liter (mg/L).

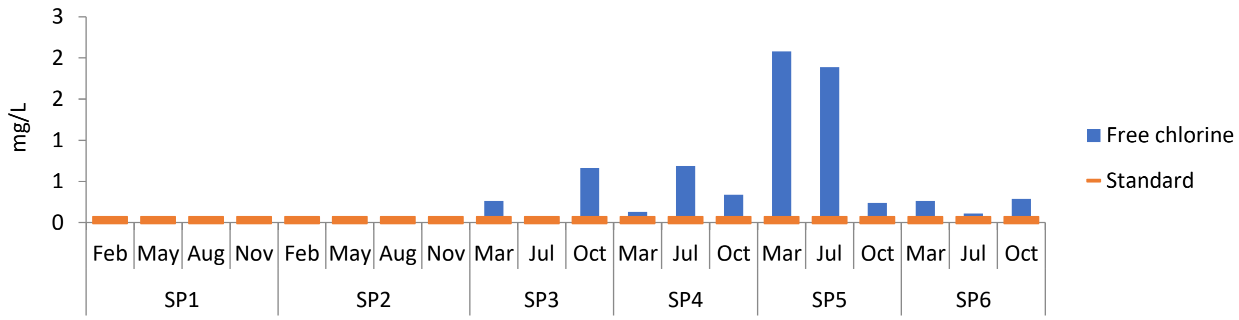

Figure 9. Comparison of free chlorine values and quality standards (mg/L).

The dissolved Co and Cu concentrations were below the quality standards at all the sampling points. In contrast, the concentrations of dissolved Ni and Zn exceeded the river water quality standards at SP1 and SP2. The cobalt concentration at all sampling points met the Class II river water quality standard, which is below 0.2 mg/L. Dissolved nickel has also been found in river water. During the dry season, the dissolved nickel concentration ranged from 0.0432 to 0.0700 mg/L; in the rainy season, it ranged from 0.0422 to 0.1220 mg/L. According to PP No. 22 of 2021, the quality standard for dissolved Nickel is 0.05 mg/L. In dry and rainy seasons, the concentrations of dissolved nickel in SP1 and SP2 exceeded the established quality standards. In the rainy season, river water in July in SP3, SP4, SP5, and SP6 exceeded the class II river water quality guidelines.

The dissolved zinc concentration in river water was found in SP1 (February) and SP2 (February) to be above the Class II River water quality standard of 0.05 mg/L. In contrast, other sampling points met the quality standards in the dry and rainy seasons. Similarly, the concentration of dissolved copper had the same pattern as the concentration of dissolved zinc, wherein in the dry and rainy seasons, only SP1 and SP2 were above the established class I river water quality standard of 0.02 mg/L, while the water concentrations in SP3, SP4, SP5, and SP6 were below the quality standard. In addition, Azizah et al. [38] Research has determined the average concentration of Cu heavy metals in the Cileungsi watershed to be 0.016 mg/L, indicating that it is below the quality norm. Heavy metals can enter water from various sources, including natural sources, weather, and anthropogenic activities.

The sources of heavy metals of anthropogenic origin are industrial and domestic waste. Paul [17] stated that industries attributed to heavy metals, come from the metal, paint, pigment, varnish, pulp, and paper industries, tanneries, refining, rayon, cotton textiles, rubber, thermal power plants, steel mills, galvanizing iron products, mining industries, as well as the use of pesticides and fertilizers containing heavy metals on agricultural land. Apart from the natural weathering of minerals, direct discharge of domestic wastewater, construction materials, ceramic units, and paints also act as nonpoint sources of these metals [39]. Industries that have the potential to pollute the Cileungsi River include the pipe industry, the tofu factory, which is a food industry, the wire and steel industry, and hospital waste containing toxic and hazardous materials [29]. The comparison graph of Nickel (Ni), Zinc (Zn), and Copper (Cu) dissolved in river water to quality standards is shown in Figure 10, Figure 11, and Figure 12.

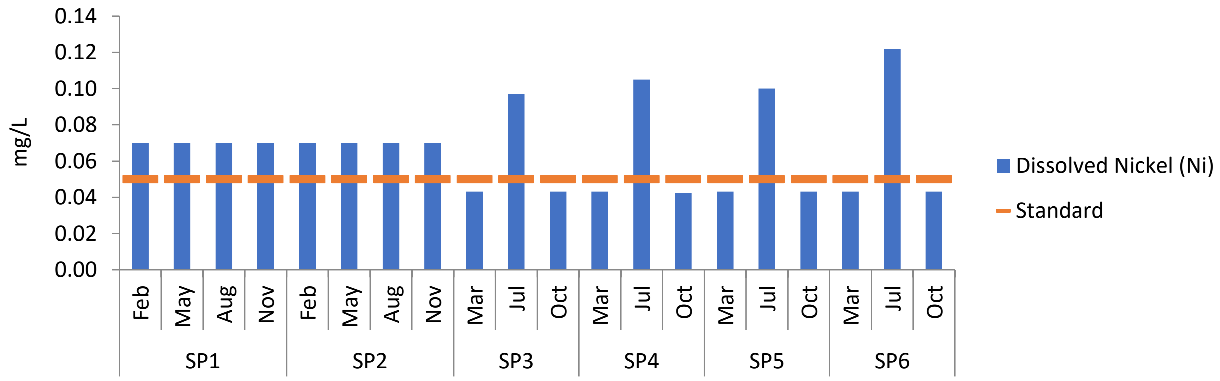

Figure 10. Comparison of dissolved nickel values and quality standards (mg/L).

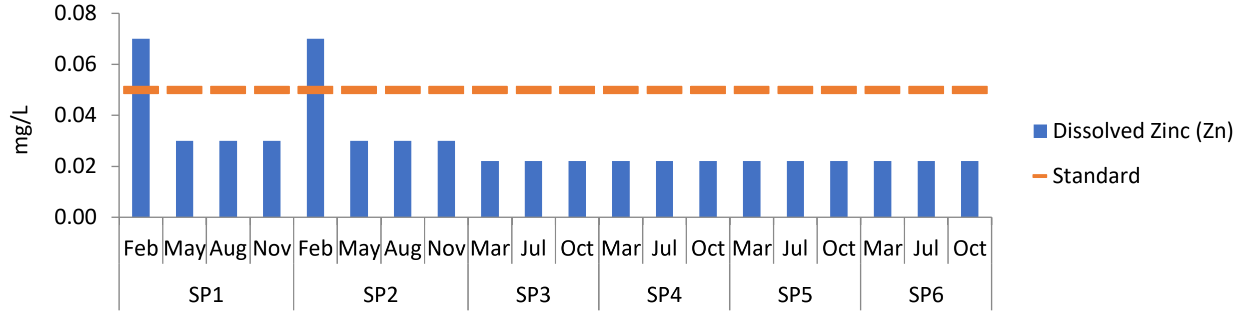

Figure 11. Comparison of dissolved zinc values and quality standards (mg/L).

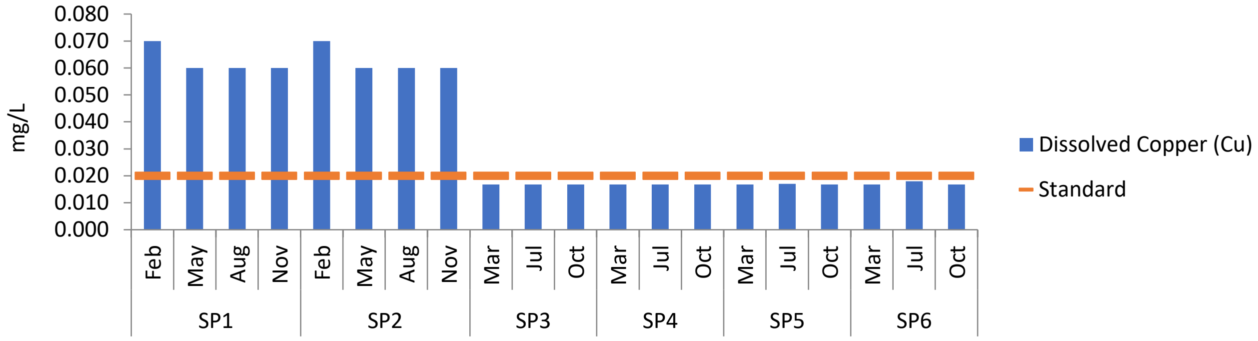

Figure 12. Comparison of the dissolved copper values and quality standards in milligrams/liter (mg/L).

The fecal coliform concentration data showed a significant increase in concentration during the rainy season compared to the dry season. The highest fecal coliform value was found in SP3 (rainy season) at 483,920 MPN/100mL, where the sampling point was on the border of Bogor Regency and Bekasi City. At this sampling point, a buildup of garbage can increase the number of fecal coliforms in the water. Escherichia coli bacteria are fecal coliform bacteria used as indicators of fecal contamination and pathogenic bacteria in food and water. Detection is easier and cheaper than the detection of pathogenic bacteria. Certain strains of *E. Coli* are known to be pathogenic, with symptoms resembling those of Cholera and Shigellosis [40]. The primary source of these bacteria is domestic waste, specifically feces. This high number is due to the high volume of domestic waste entering the waters of the Cileungsi River. According to Li et al. [41], urban domestic waste and agricultural activities are the primary sources of FC pollution in the river. In the Cileungsi Sub-DAS area, there are residential areas that could pollute the Cileungsi River, such as the Legenda Wisata and Kota Wisata housing complexes in Cibubur and the Villa Nusa Indah and Harmony housing complexes in Gunung Putri [28]. A graph comparing fecal coliforms in river water with quality standards is shown in Figure 13.

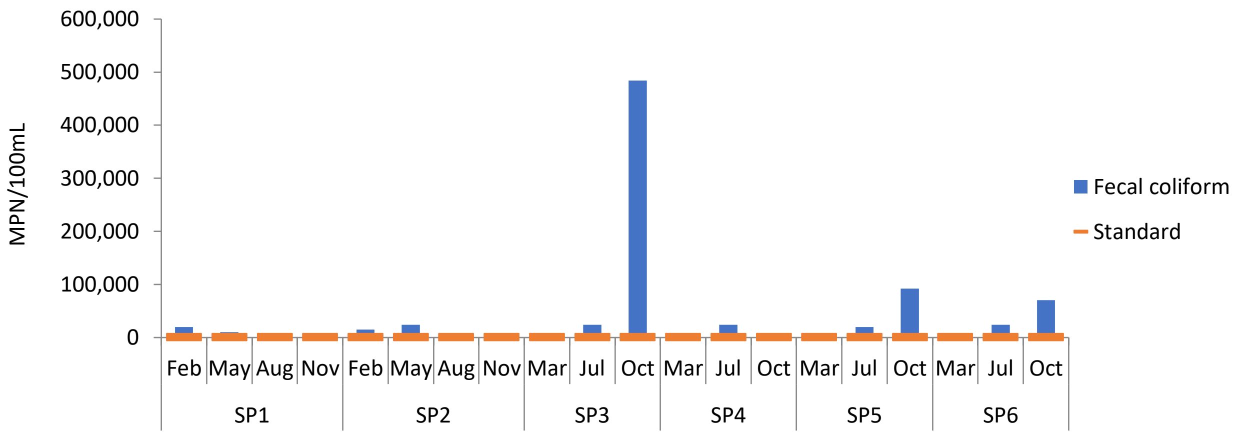

Figure 13. Comparison of the fecal coliform value and quality standards in Most Probable Number (MPN)/100 milliliters (mL).

Water Quality Assessment in Cileungsi River

In the end of the season, the pollution index in SP1 (February) and SP5 (March) falls into the moderately polluted category, with pollution index values of 5.49 and 7.30, with SP5 (March) having the highest PI value. In comparison, the other sampling points fell into the lightly polluted category. Activities with the highest potential for polluting SP5 include cooking oil, electronics, textiles, leather tanning, basic oleochemicals, and plywood. The pollution index in the rainy season indicates that only one sampling point, SP3 (October), falls into the category of heavily polluted, with a PI value of 10.30. The sampling points that fell into the moderately polluted category were SP3 (July), SP4 (July), SP5 (July), SP5 (October), SP6 (July), and SP6 (October), with PI values of 5.67, 5.71, 7.17, 7.73, 5.68, and 7.32, respectively. The other sampling points were in the lightly polluted category. When viewed from these two images, the river water in SP2 was consistently classified as light-polluted.

At point SP4, the pollution index value decreased compared to the one at SP3. This decrease could occur because the river can restore itself (self-purification) from pollutants when the organic content decreases, as indicated by the decreasing BOD value compared to the previous point. Self-purification in rivers can occur by adding dissolved oxygen from the air to the river water. The Curug Parigi waterfall, located between points SP3 and SP4, initiates the reaeration process, which increases the oxygen concentration in the water due to turbulence, allowing oxygen to diffuse from the air into the water. The SP3 point is located on the border between Bogor Regency and Bekasi City, an area densely populated with residential areas. The dense population around the SP3 point generates a higher volume of domestic waste, which, when it enters the Cileungsi River, contributes to increased water pollution in the Cileungsi River. The increase in domestic waste is evident in the very high fecal coliform value found at the SP3 point, indicating that a communal wastewater treatment installation is needed in every housing complex surrounding the Cileungsi River. Community participation is also required to prevent garbage from being thrown directly into the river.

Conclusion

The results of testing the water quality of the Cileungsi River showed several parameters that exceeded the quality standards of Class II river water. Parameters exceeding the quality criteria include TSS, BOD, COD, NO2-, NH3, Free Chlorine, Ni, Zn, Cu, and fecal coliforms. Thus, this poses a potentially significant risk to individuals using water from the Cileungsi River as raw water for drinking and recreational purposes. As a result, the parameters that require attention are BOD, $NO2^-$, free chlorine, and fecal coliforms, which serve as markers of pollution from household and agricultural activities. The PI values obtained at the six sampling points during the dry season ranged from 2.73 to 7.30, while they ranged from 3.00 to 10.30 during the rainy season. During the dry season, the pollution index (PI) at the sampling points located at the Regional Water Company bridge in Kota Wisata Cibubur and PT Rahayu Indah Kulit falls within the medium-pollution category. In contrast, the PI in the rainy season was obtained at sampling points at the border of Bogor Regency and Bekasi City, which includes the heavy pollution category. Based on the results of this study, a strategy is needed to manage them water quality of the Cileungsi River in the future, such as determining the capacity to accommodate pollution loads, creating communal wastewater treatment plants for settlements around the Cileungsi River, enforcing laws for communities and industries that dump waste into the river, and increasing community participation.

Author Contributions

DPM: Conceptualization, Methodology, Investigation, Formal Analysis, Visualization, Writing; **RS:** Conceptualization, Methodology, Formal Analysis, Visualization; **SH:** Conceptualization, Methodology, Formal Analysis, Visualization; **LRK:** Conceptualization, Methodology, Formal Analysis, Visualization.

Conflicts of Interest

There are no conflicts to declare.

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