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Comparative study of water quality of *Cikapundung River* in Citarum Subwatershed

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Abstract
The Cikapundung River was part of the Citarum Watershed that flowed from North Bandung to the South. Cikapundung River water experienced pollution during the irrigation process from upstream to downstream, which was caused by activities in residential areas, markets, and industries. Based on this, research was needed to determine the quality of Cikapundung River water using macrobenthos indicators. Macrobenthos was considered a bioindicator of water quality because its presence could change according to the level of pollution in the aquatic ecosystem. The research method used was laboratory testing, which compared three locations in the Cikapundung River: Taman Sari (Station one), Kordon Market (Station two), and Citepus (Station three). Water samples were taken from the three stations for laboratory tests, and the macrobenthos present in these waters were identified. The results showed that Station one had a Diversity Index of 1.423, a Diversity Index of 0.684, and a Dominance Index of 0.318, with a temperature of 24.9°C, turbidity of 63, TDS of 87 ppm/3.44333 mg/L, TSS of 375 mg/L, pH of 6.0, DO of 3.0, COD of 174 mg/L, and BOD5 of 13.5 mg/L. Station two had a Diversity Index of 1.158, a Diversity Index of 0.557, and a Dominance Index of 0.378, with a temperature of 26.6°C, turbidity of 46.2, TDS of 199 ppm/2.5345 mg/L, TSS of 39 mg/L, pH of 6.5, DO of 2.9, COD of 251 mg/L, and BOD5 of 21 mg/L. Station three had a Diversity Index of 1.216, a Diversity Index of 0.104, and a Dominance Index of 0.625, with a temperature of 31°C, turbidity of 93.8, TDS of 732 ppm/1.98777 mg/L, TSS of 3042 mg/L, pH of 7.5, DO of 1.7, COD of 696 mg/L, and BOD5 of 37 mg/L. Based on this, it could be concluded that Station one was in a lightly polluted position, Station two was in a moderately polluted position, and Station three was in a heavily polluted position. The primary purpose of this study was to assess the water quality of the Cikapundung River using macrobenthos as bioindicators, in order to determine the extent of pollution across different sections of the river. It is recommended that local authorities implement stricter regulations on waste management from residential, market, and industrial areas along the Cikapundung River to reduce pollution in the river.

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1. Introduction

Rivers are an important part of the hydrological cycle and have benefits in maintaining the continuity of living things around them. Rivers are a source of life for humans, animals and plants. The existence of rivers for humans has many benefits, especially for raw water sources, irrigation of agricultural land and fish farming. *Cikapundung River* is an important river for the people of Bandung City. The river flows from North Bandung and empties into the Citarum River in the south with a

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distance of about 28 km. The river is part of the Citarum sub-watershed which functions as a source of raw water, main drainage and power generation.

Land use changes along the *Cikapundung River* affect the quantity and quality of water. Based on observations, the water quality of the *Cikapundung River* continues to decline. This condition can be seen from settlements along the river border discharging their waste directly into the river, waste from the market and industry. Water quality indicators can be determined by measuring the quality standards of several physical factors, namely temperature, turbidity, Total Dissolved Solid (TDS), Total Suspended Solid (TSS). Then chemical factors, namely pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biohemical Oxygen Demand (BOD). So the presence of macrobenthos can change according to the level of pollution in the aquatic ecosystem. Therefore, macrobenthos are considered as biodicators in determining water quality. Polluted river water conditions will have an impact on the presence of macrobenthos. Macrobenthos are organisms that live on the surface of waters or in the bottom of waters that have a size of > 0.5 mm. The presence of macrobenthos in river water determines the quality of the river water.

Macrobenthos are considered biodicators of water quality, according to Rahadrjanto & Husamah (2019) biodicators are species or groups of species that can reflect the state of the abiotic or biotic environment, represent the impact of environmental changes on habitats, communities, or ecosystems and indicators of taxa diversity or overall diversity in an area. So the presence of macrobenthos can change according to the level of pollution in the aquatic ecosystem. Based on this, research is needed to determine the water quality of the *Cikapundung River* in the upstream, middle and downstream. The indicators measured are based on physical and chemical factors and the presence of macrobenthos living in the region. Based on this, research was needed to determine the quality of *Cikapundung River* water using macrobenthos indicators.

2. Method

This research used an exploratory method, which involved direct observation and sampling at the research site. The population in this study was the Cikapundung River, a sub-watershed of the Citarum River, with a distance of 28 km from upstream to downstream, passing through 9 sub-districts and 13 villages. The sampling technique used was purposive sampling to determine the sampling locations. The sample locations were chosen based on considerations of the topographic conditions of the environment, the benefits of the river for the surrounding land, and the use of the river around the lower reaches of the Cikapundung River.

The research samples were taken from three locations: upstream in Taman Sari, midstream in Pasar Kordon, and downstream in Citepus. From these locations, both river water and macrobenthos samples were collected. The macrobenthos samples were then cleaned and preserved (Suwondo et al., 2004). The collected biota were labeled for easy identification, while the water samples were placed in 1.5 ml bottles and sent to the Ecology Laboratory of the Padjadjaran University Centre for Environmental Excellence and Sustainability Science for testing based on the Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning River Water Quality Standards.

Macrobenthos sampling was conducted by continuously exploring the riverbank, collecting the organisms, and then separating them according to their type. The macrobenthos samples were preserved using resin for identification. The data obtained were then analyzed to determine the river water quality and macrobenthos diversity at the three stations. The analysis involved calculating the diversity index, uniformity index, and degree of water pollution. The data analysis technique used to calculate the diversity index was the Shannon Wiener diversity index formula (Meisaroh et al., 2019).

$$H' = -\sum Pi \, LN \, Pi \qquad (1)$$

Description:
H' = Diversity index,
Pi = the ratio of the number of individuals of species k-1 to the total number,
LN = Total number of individuals of all species.

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Shannon-Wiener index value categories have a certain range, namely; H‘ < 1 indicates low diversity, 1 < H’ < 3 indicates moderate diversity, H' > 3 indicates high diversity. Then the following was a classification table of the degree of water pollution based on the macrobenthos index.

Table 1
Classification of Water Pollution Degree Based on Macrobenthos Index

Index	Level of Pollution
<1.0	Heavily Polluted
1.0-1.3	Moderately Polluted
1.4-2.0	Lightly Polluted
>2.0	Not Polluted

Source: Rachman et al., (2016)

Then also analysed the uniformity index, according to Krebs (1989) in Meisaroh, et al. (2019) using the following formula.

$$E = \frac{H'}{LN\ S} \qquad (2)$$

Description:
H' = Uniformity Index,
S = Number of all species,
LN = Total number of individuals of all species.
The criteria for uniformity as follows E < 0.4 indicates a low level of uniformity; 0.4<E<0.6 indicates a moderate level of uniformity; E> 0.6 indicates a high level of uniformity (Brower et al.1990). Furthermore, to analyse the dominance index using Simpson's dominance index formula, namely:

$$C = \sum(ni/N)2 \qquad (3)$$

Description:
C = Dominance Index
ni = Number of individuals of each species
N = Number of all individuals of the species
The dominance index criteria were classified as follows; 0 < C < 0, 3 indicates low dominance; 0, 3 < C < 0, 6 medium dominances; 0, 6 < C < 1 high dominance (Odum, 1993 in Meisaroh, et al., 2019).

3. Results and Discussion

3.1 River Water Quality Standards

River water quality standards are regulated according to Government Regulation No. 22 of 2021 concerning water designation and river water quality standards, which are as follows:

1) class I, can be used as raw water for drinking water, and or other needs that require water quality equivalent to the above purposes.
2) class II, can be used for water entertainment infrastructure, animal husbandry, freshwater fish farming, crop irrigation, and or other needs that require water quality equivalent to the above purposes.
3) class III, can be used for animal husbandry, freshwater fish farming, crop irrigation, and or other needs that require water quality equivalent to the above purposes.
4) class IV, can be used for irrigation of crops and/or other purposes, and the water quality must be in accordance with these purposes.

Water quality parameters include physical and chemical aspects of water. The following are water quality parameters based on physics, namely:

1) Water temperature, according to Fadholi (2013) temperature can be defined as a measure of the level of heat or coldness of water.
2) Water turbidity, according to Hendrawan 2005 in (Tezia, 2020), turbidity is when the clarity of a liquid is reduced due to the presence of other substances.

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3) Total Dissolved Solid or abbreviated to TDS indicates the content of inorganic salts and some organic compounds dissolved in water (Ibrahim et al., 2020).
4) Total Suspended Solid (TSS). According to APHA (2005) Total Suspended Solid or total suspended solids are all residual solids retained by filters with a maximum particle size of 2 μm or 10 μm larger than the colloidal particle size. TSS includes sludge, clay, metal oxides, sulfides, algae, bacteria, and fungi.

Furthermore, the water chemistry parameters include:

1) pH is a value that indicates the level of acidity or basicity of water which functions as a limiting factor for the life of living things (Ibrahim, et al., 2020).
2) Dissolved Oxygen (DO) is the amount of oxygen dissolved in a certain volume of water at a certain temperature and atmospheric pressure. (Sulaeman et al., 2020).
3) Chemical Oxygen Demand (COD) is the amount of oxygen needed to reduce all organic matter contained in water (Custodio et al., in Haniyyah 2022).
4) Biohemical Oxygen Demand (BOD) according to Wardhana (2004) is the amount of oxygen needed by microorganisms in water to break down (degrade) organic matter in the water called BOD.

Physical and chemical parameters of river water determine the presence of macrobenthos as biodicators of *Cikapundung River* water quality. Biodicators are species that are sensitive to processes or pollutants that alter biodiversity. According to Schneider et al. (2010), they are used to identify environmental changes and show their positive or negative effects. As pollutants are present, biodicators can locate benthic diversity and species. Biodicator species are resistant to environmental changes, so they can be monitored well.

Then the size limit of water quality parameters for each water class is mentioned in Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Water Quality Management and Pollution Control in Table 2 as follows:

Table 2
Water Quality Standard

Parameter	Unit	Quality Standard			
		I	II	III	IV
Temperature	^{0}C	Dev 3	Dev 3	Dev 3	Dev 3
pH	-	6-9	6-9	6-9	6-9
DO	Ppm	6	4	3	1
COD	mg/L	10	25	40	80
BOD	mg/L	2	3	6	12
TDS	mg/L	1000	1000	1000	1000
TSS	mg/L	40	50	100	400

Source: Indonesian Government Regulation No. 22 of 2021

3.2 Measurement Results of *Cikapundung River* Water Quality

Based on laboratory testing measurements of samples taken from three locations, the following are the results of the *Cikapundung River* water quality standard measurements.

1) Temperature

Measurement of this parameter using TDS and EC Meter. The results of temperature measurements at both stations ranged from 24.9^{0}C-26.6^{0}C. based on the data above, the temperature value is still at the threshold of the standard value of water quality standards according to PP No. 22 of 2021, which is in the range of 20-30 ^{0}C. Meanwhile, station three is above the quality standard of more than 30^{0}C which results in a 10-43% decrease in the abundance of macrobenthos in the river. For more details can be seen in the following table.

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Table 3
Cikapundung River water temperature

Station	Location	Temp	Quality Standard	Description
1	Taman Sari	24,9 ^{0}C	20-30 ^{0}C	Tolerate
2	Pasar Kordon	26,6 ^{0}C	20-30 ^{0}C	Tolerate
3	Citepus	31 ^{0}C	20-30 ^{0}C	Intolerant

Source: Research, 2024

2) Turbidity

Based on the laboratory test results of the Ecology Centre of Excellence for Environment and Sustainability Science, Padjadjaran University, it can be seen in Table 4 below.

Table 4
Turbidity of Cikapundung River Water

Station	Location	Turbidity	Quality Standard	Description
1	Taman Sari	63	50	Slightly Dark
2	Pasar Kordon	46,2	50	Bright
3	Citepus	93,8	50	Very Dark

Source: Research, 2024

Based on Table 4, the results show that the low turbidity value is at station two, this is indicated by its turbidity value of 46.2 which is below the quality standard, therefore sunlight can easily penetrate to the bottom of the water. Station one has a turbidity value of 63 which can be said to be a little dark therefore sunlight can still penetrate the riverbed but takes some time, while station three shows a value of 93.8 this indicates that sunlight can no longer penetrate the bottom of the waters.

3) Total Dissolved Solid (TDS)

The following is Table 5 which shows the results of Total Dissolved Solid (TDS) measurements at three sample locations in the Cikapundung River.

Table 5
Total Dissolved Solid (TDS) of Cikapundung River

Station	Location	*TDS*	Quality Standard	Description
1	Taman Sari	87 ppm/3,433 mg/L	1000 mg/L	low
2	Pasar Kordon	199 ppm/2,534 mg/L	1000 mg/L	low
3	Citepus	732 ppm/1,987 mg/L	1000 mg/L	low

Source: Research, 2024

4) Total Suspended Solid (TSS)

The following is Table 6 which shows the measurement results of Total Suspended Solid (TSS) at three sample locations in the Cikapundung River.

Table 6
Total Suspended Solid (TSS) of Cikapundung River

Station	Location	*TSS*	Quality Standard	Description
1	Taman Sari	375 mg/L	50 mg/L	exceeds
2	Pasar Kordon	39 mg/L	50 mg/L	under
3	Citepus	3042 mg/L	50 mg/L	exceeds

Source: Research, 2024

Based on the measurement results of Total Suspended Solid (TSS) in Table 5, it shows that the first location in Taman Sari and the third location in Citepus exceeded the quality standards. While in the second location, namely Kordon Market, it is still below the quality standard.

5) pH

The following table shows the pH measurement results from the three sample locations.

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Table 7
pH of Cikapundung River Water

Station	Location	*pH*	Quality Standard	Description
1	Taman Sari	6	6-9	Tolerate
2	Pasar Kordon	8	6-9	Tolerate
3	Citepus	8,5	6-9	Tolerate

Source: Research, 2024

Based on the pH measurement results listed in Table 7, it shows that based on the water quality standard threshold contained in Government Regulation Number 22 of 2021, which is in the range of 6-9, so that all sample locations have an acidity level that is still safe for the survival of aquatic biota.

6) Dissolved Oxygen (DO)

The following is Table 8 which shows the test results of Dissolved Oxygen (DO) of *Cikapundung River* water at three sample locations.

Table 8
Dissolved Oxygen (DO) Measurement Results of Cikapundung River

Station	Location	*DO*	Quality Standard	Description
1	Taman Sari	3	Minimum limit 4	lightly polluted
2	Pasar Kordon	2,9	Minimum limit 4	moderately polluted
3	Citepus	1,7	Minimum limit 4	heavily polluted

Source: Research, 2024

Table 8 shows that the highest DO value is located at station one where station one is located in the highland area. Highland areas generally have a fairly high dissolved oxygen content. However, all sample locations are below the minimum limit so it is concluded that the three sample locations have experienced pollution. At the location in Taman Sari, it is categorised as lightly polluted, at the Kordon Market location it is categorised as moderately polluted and at Citepus it is categorised as heavily polluted.

7) Chemical Oxygen Demand (COD)

The measurement results of Chemical Oxygen Demand (COD) can be seen in Table 9 below.

Table 9
Measurement Results of Chemical Oxygen Demand (COD) of Cikapundung River

Station	Location	*COD*	Quality Standard	Description
1	Taman Sari	174	100 mg/L	lightly polluted
2	Pasar Kordon	251	100 mg/L	moderately polluted
3	Citepus	696	100 mg/L	heavily polluted

Source: Research, 2024

Table 9 shows the COD value at each station, according to Effendi (2003) COD requirements describe the total amount of oxygen needed to oxidise organic matter chemically, both biologically degradable and difficult to degrade bilogically. Into CO2 and H2O so that all kinds of organic matter, both easily decomposed and difficult to decompose, will be oxidised. With the amount of organic matter that is difficult to decompose in the waters. So COD describes the total amount of organic matter present. The highest number is at station three (Citepus) which is 696 and the lowest value is at station one which is 174. The third location or Citepus has the highest value or heavy pollution level is possible because the location is an industrial area.

8) Biohemical Oxygen Demand (BOD)

The following is Table 10 which shows the measurement results of the Biohemical Oxygen Demand (BOD) of the Cikapundung River.

Table 10
Biohemical Oxygen Demand (BOD) of Cikapundung River

Station	Location	*BOD*	Quality Standard	Description
1	Taman Sari	13,5	10 mg/L	lightly polluted
2	Pasar Kordon	21	10 mg/L	moderately polluted
3	Citepus	37	10 mg/L	heavily polluted

Source: Research, 2024

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Based on table 10 shows the value of BOD which can indicate the level of organic matter in the water so that it can be used to measure the presence of pollution in the waters, the greater the value of BOD in a water body, the greater the level of pollution that occurs. The highest BOD5 value is at station three around 37 mg/L which is in the industrial area.

9) Macrobenthos Identification

Based on the results of macrobenthos identification at three locations (stations) representing the upstream, middle and downstream parts of the river can be seen in Table 11 below.

Table 11
Macrobenthos Identification Results

Fillum	Class	Spesies	Station			Total Individuals
			1	2	3	
Mollusca	Gastropoda	*Spesies 1*	2	1	0	3
		Spesies 2	56	25	5	86
		Spesies 3	15	10	15	40
		Spesies 4	29	10	0	39
Arthtopoda	Insecta	*Spesies 1*	2	0	0	2
		Spesies 2	8	1	0	9
Annelida	Clitella	*Spesies 1*	1	0	0	1
		Spesies 2	3	0	0	3

Source: Research, 2024

Based on the identification results obtained, then analysed using the Shannon Wiener diversity index (H'), Krebs Uniformity (E), Simpson's Dominance Index (C) can be seen in Table 12 as follows.

Table 12
Diversity, Uniformity and Dominance Indexes

Index Type	Station 1 (Taman Sari)	Station 2 (Pasar Kordon)	Station 3 (Citepus)
Diversity (H')	1,423	1,158	0,216
Uniformity (E)	0,684	0,557	0,104
Dominance (C)	0,318	0,374	0,625

Source: Research, 2024

Based on Table 12, it can be seen that the highest Diversity Index is at station one (1.423). Then based on the diversity index, stations 1 and 2 macrobenthos diversity is in the medium category because H‘ is in the position of 1 < H’ 3. And for station three has a value of H' in the position < 1 this indicates that the diversity is low.

The highest macrobenthos uniformity index value is at station one because E is in the position of E > 0.6. Then at station two has the value of E in the position of 0.4 < E < 0.6 < this indicates that the uniformity of macrobenthos is moderate. And for station three has an E value in the position of E <0.4 this indicates that the diversity is low.

The highest dominance index value is at station three because the value of C = 0.625 is in the position of 0.6 < C < 1 this indicates that at station three has a high dominance of macrobenthos, in other words macrobenthos that live are dominated by one or two types only. whereas, at station one has a value of C = 0.318 is in the position of 0 < C < 0.3 this indicates that the dominance of macrobenthos is low. And for station two has a value of C = 0.374 is in the position of 0.3 < C < 0.6 this indicates that the dominance of the medium.

4. Conclusions

Based on the discussion that has been presented, it can be concluded that the comparison of the water quality of the *Cikapundung River* upstream, middle and downstream has a significant difference. Station one based on the results of the calculation of the diversity index, uniformity and dominance index which shows that at station one the level of diversity is still high and there are still many types of macrobenthos species that can live in these waters, this is reinforced by laboratory results on the physical and chemical aspects of river water and based on the state of macrobenthos it is concluded that station one is in a mildly polluted position. Then station two based on the results of the calculation of diversity

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index, uniformity and dominance index which shows that in station two decreased macrobenthos diversity but there are still many types of macrobenthos species that can live in these waters, the conclusion is that station two is in a moderately polluted position. Finally at station three based on the results of the calculation of the diversity index, uniformity and dominance index which shows that at station three there is a decrease in diversity and an increase in the dominance value, this shows that the waters are only dominated by one or two sepsies, this indicates that the diversity of macrobenthos in these waters is very low so it can be concluded that station three is in a heavily polluted position.

Based on the comparison of three locations in the Cikapundung River, it can be concluded that the third station in Citepus is the part of the river with the lowest water quality. This can occur because the third station in Citepus is an industrial area. The existence of an industrial area where the *Cikapundung River* flows has an influence on the low quality of the river water. A comprehensive effort is needed to overcome these problems, in an effort to preserve the aquatic environment. Based on the findings, it is recommended that local authorities take immediate action to reduce pollution in industrial areas, particularly in the Citepus region, by enforcing stricter waste management regulations and promoting cleaner production practices to improve the water quality of the *Cikapundung River*. Additionally, it is recommended that ongoing monitoring and assessment of the river's water quality and macrobenthos diversity be conducted regularly, with targeted efforts to restore habitats and mitigate pollution sources, ensuring sustainable management of the river's ecosystem.

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