Macozoobenthos diversity as a bioindicator for the pollution status of Citarik River, West Java

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Abstract. Citarik River is one of the sub-watersheds of the Citarum River, which flows through to three administrative regions, namely Bandung Regency, Garut Regency, and Sumedang Regency. Citarik River is used for irrigation to support ponds and rice fields, however many industrial wastes and domestic wastes were disposed into Citarik River therefore it causes river water pollution. Macrozoobenthos diversity is an index that can be used to determine the pollution status of the river. The study was conducted between March to April 2019 at four sampling stations for four sampling times. All sampling stations are located in Bandung Regency. Station 1,2,3,4 are located in Mt. Kareumbi, Cicalengka, Haurpugur, and Solokan Jeruk, respectively. The highest value of diversity index of macrozoobenthos was observed at station 1 with the value of 2.01, whereas the lowest was at station 4 with the value of 0.69. The dominant species at station 4 are Pomacea sp. and Filopaludina sp. Both species belong to the class of gastropods. Based on the diversity index of macrozoobenthos, the pollution status of Citarik River at station 1 was an unpolluted category, station 2 was medium polluted, station 3 and 4 have been polluted heavily.

1. Introduction

Citarik River is one of the sub-watersheds of Citarum River, which flows through three regencies, that are Bandung, Garut, and Sumedang within the altitude of 700 – 1,500 meters above sea level. The upper stream of Citarik River flows start from Mt. Kareumbi. Citarik River is very important for the daily life of the community around the river. It supplies clean water to Bandung Regency area, and also irrigates rice fields about 10,702.89 ha. It is necessary to know the pollution status of the river, and good river management should be implemented to maintain water quality in this river [21].

One of the biotas that can be used as a biological parameter in determining the condition of the water is macrozoobenthos because it is permanent (sessile) and has a high sensitivity to environmental changes [15]. Changes in water quality and substrate affect the abundance and diversity of macrozoobenthos. This abundance and diversity depend on their tolerance and sensitivity to the environmental changes that consist of biotics and abiotics. Good quality waters usually have high species diversity and vice versa in poor or polluted waters usually have low species diversity [4].

The objective of this research is to determine the pollution status of Citarik River, based on diversity index of macrozoobenthos. The result of this study can be used as basic information to make guidance of river management of Citarik River, therefore the ecological function of Citarik River as water resources could be sustainable.
2. Methodology

2.1. Location and time

Sampling was carried out at 4 stations within 7 days interval. The sampling station was determined according to the environmental conditions. Station 1 represents the upper stream of Citarik River located on the Mountain Kareumbi, Sub-district Cicalengka. There were not found anthropogenic activities around this station. Station 2 represents the middle part of Citarik River that is located in Sub-district Cicalengka of Bandung Regency were close to residential settlements. Station 3 also represents the middle part of Citarik River located in Haupugur Village of Bandung Regency, its vicinity is residential neighborhoods and textile industries. The downstream segment is represented by station 4 which is located in Rancaek District of Bandung. Many textile manufactures are around station 4 and some of them are disposed their industrial wastes to the river (figure 1).

![Figure 1. Map of research location on the Citarik River.](image)

2.2. Physical and chemical parameters analysis

The physical and chemical parameters that were measured in this study including water current, transparency, temperature, and total suspended soil (TSS). The current water was measured using an alleged ball tied to a rope two meters long, an alleged ball was released on the surface of the river along with the stopwatch, then the stopwatch automatically calculated the comparison between the distance and the time required for the ball to reach it. Transparency measurements were performed with a Secchi disk, inserted into the waters and the recording was made on how far the disk went into the water until a contrast in colors was not visible. Water temperature was measured by using a water thermometer.

2.3. Macrozoobenthos analysis

The sampling of macrozoobenthos in each station was further sub-divided into five plots of 1m x 1m size. The macrozoobenthos in the surface and bottom of the river were taken by Surber mesh. The samples obtained were washed with water and put into a plastic bag containing 70% alcohol for preservation and then labeled. The samples were identified with the identification book of Pennak [13].

2.4. Data analysis

Analysis of samples was conducted on the diversity index, density, and equability macrozoobenthos as well as physical and chemical water quality.
1. Shannon-Wiener Diversity Index (H‘)
\[ H' = -\sum (p_i \log_2 p_i), \text{ where } p_i = \frac{n_i}{N} \]
Information:
H’ = diversity index, \( n_i \) = Number of individuals of species
N = Number of individuals in the community

2. Evenness Index (E)
\[ E = \frac{H'}{H_{\text{max}}} \]
Information:
E = Evenness Index
H’ = Diversity Index
H_{\text{max}} = \ln S
S = Number of Species

3. The density of macrozoobenthos
\[ K = \frac{a}{b \times n} \]
Information:
K = density of macrozoobenthos (individual/m²)
a = Number of individuals of macrozoobenthos (Individual)
b = Jala Surber = area (m²)
n = number of replicates decision

2.5. Pollution status determination
Determination of the water pollution status in this research is determined based on the diversity index of Macrozoobenthos. The diversity index was calculated according to the Shannon-Wiener index formula. The classification of the annexation index can be seen in table 1.

| No. | Pollution degree | Diversity Index |
|-----|------------------|-----------------|
| 1   | \( H > 2 \)      | Not contaminated yet |
| 2   | \( 1.6 < H \leq 2 \) | Lightly polluted |
| 3   | \( 1 < H \leq 1.5 \) | contaminated medium |
| 4   | \( H < 1 \)      | Tainted weight   |

Physical and chemical parameters can determine the status of the water pollution and also become the life support for macrozoobenthos. The physical and chemical factors are important for the sustainability of organism and their population [16].

3. Results and Discussion

3.1. Macrozoobenthos abundance
The results showed that the highest abundance of macrozoobenthos in Citarik River was found at Station 1 with a value in the range of 27 – 47 ind/m² whereas the lowest abundance was found at Station 4 with a value in the range of 3-7 ind/m² (table 2). Environmental conditions in Station 1 are still good where there was not found the industrial and domestic wastes. Besides, the life support factors for macrozoobenthos such as temperature does not exceed the maximum limit for macrozoobenthos that is ranged at 35 – 40°C, the pH at Station 1 is neutral, it also supports the life of macrozoobenthos. The pH value that supports the life of macrozoobenthos in particular from the phylum Mollusca is 5.7 – 8.4 [13].
Table 2. Macrozoobenthos abundance in Citarik River.

| Species          | Station 1 | Station 2 | Station 3 | Station 4 |
|------------------|-----------|-----------|-----------|-----------|
|                  | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Progomphus sp.   | 12 | 3 | 12 | 10 |
| Enallagma sp.    | 15 | 6 | 16 | 8 |
| Lumbriculus sp.  | 25 | 21 | 21 | 12 | 32 | 12 | 22 | 15 | 22 | 18 | 12 | 5 | 2 |
| Melanoides sp.   | 27 | 18 | 20 | 12 | 6 | 4 | 7 |
| Lymnaea sp.      | 32 | 26 | 18 | 18 |
| Libellula sp.    | 11 | 12 | 14 | 10 |
| Ranatra sp.      | 2 |
| Tubifex sp.      | 11 | 12 | 8 | 4 |
| Laccophylus sp.  | 2 | 2 |
| Hydropsychidae   | 3 |
| Gomphus sp.      | 2 |
| Tipula sp.       | 1 | 5 |
| Chironomus sp.   |        |
| Parathelphusa sp.| 7 | 5 | 7 | 7 | 5 | 3 |
| Pomacea sp.      | 5 | 7 | 3 | 4 | 5 | 4 | 2 | 12 | 6 | 8 | 7 |
| Filopaludina sp. | 3 | 4 | 2 | 8 | 3 | 5 | 2 |

| Amount Abundance (ind/m²) | 142 | 89 | 118 | 82 | 54 | 24 | 36 | 34 | 34 | 27 | 18 | 10 | 22 | 9 | 13 | 9 |
|---------------------------|-----|----|-----|----|----|----|----|----|----|----|----|----|----|---|---|---|
|                           | 47  | 30 | 39  | 27 | 18 | 8 | 12 | 10 | 11 | 9 | 6 | 3 | 7 | 2 | 4 | 3 |

Station 4 had the lowest abundance with 4 individual/m², the density of macrozoobenthos is influenced by their habitat, that have been polluted. The supporting factor of macrozoobenthos’s life at 4 stations are very low, such as the pH reaching the maximum level of macrozoobenthos tolerance of 8.8. Macrozoobenthos density can depict the contaminated or not contaminated of water with a low or high density, but can not be used to establish pollution status as it is still needed other supporting data to set it. Also, there is no density index showing the pollution level of water.
Figure 2. Density, diversity, and evenness of macrozoobenthos in Citarik River, West Java.

The range of Evenness Index in the Citarik River ranged from 0.24-0.45, according to Odum [12]. Equability Index (E) ranged from 0-1. The closer to zero, the less similar the population becomes, meaning that the spread of the number of the individuals of each species is not the same, and there is a tendency of one type of species to dominate. Due to the dominating type, equability means low when its value approaches 0 and when equability approaching 1, it indicates no type is dominating. The lowest evenness was observed in station 4 with an average value of 0.27 and the highest in station 1 with an average value of 0.41. These results showed that occurred species dominated that was Lumbriculus sp., Lymnaea sp., and Melanoides sp.

The existence of aquatic insects, in particular the order of Ephemeroptera, Plecoptera, and Tricoptera, indicate that the waters still have good quality [10]. With the discovery of some insects in water particularly such Laccophylus sp. derived from the order Tricoptera, the water quality at Station 1 can categorize as good enough. The Stations 2 and 3 also have a low Equability index value, Station 2 with a value of 0.3 and Station 3 was 0.32. The Stations 2 and 3 dominating species is the same that are Lumbriculus sp. and some species from the Gastropoda class. The Station 4 which has a very low Equability value has 2 dominating species, they are Pomacea sp. and Filopaludina sp. Both species are included in the class of Gastropods. Jailani and Nur [5] said that the macrozoobenthos of the Gastropoda class can survive in various places beyond other classes and have a good level of adaptation and need sufficient organic content on the substrate to live. Because of the Stations 4 were dominated by the Gastropod class, it is showed that it has been polluted. Dominance of some species is caused by only a few certain species that have a tolerance level to the environmental condition of the area. This Equability shows the balance of each species [8].

The index of the macrozoobenthos diversity in the Citarik River has a range from 0.52-2.03. The diversity of macrozoobenthos with the highest average was at station 1 with a value of 2.01 and the lowest was at Station 4 with a value of 0.69. The value of this diversity relates to environmental conditions affecting the level of macrozoobenthos tolerance. Because of the tolerance of macrozoobenthos, each type is different. Low diversity index shows that the site has been polluted thus only a few macrozoobenthic species can survive. On the other hand, high diversity index reveals
that the site has a good environmental quality thus many macrobenthic species are able to adapt to this environment [12]. The value of diversity index at the Station 1 was in the range of 1.8-2.08. It means that the status of this station has not been polluted by any waste, and still has good environmental conditions for the life of macrozoobenthos.

Station 1 is far from the residential settlements and there were not any anthropogenic activities around the river so it has good environmental conditions. At station 2, the value of the diversity index has a range of 1.02-1.2, it means this station has been contaminated. Station 2 is located close to residents and farms, therefore it is accumulated by various waste. The Station 3 has a diversity value with a range of 0.84-1.02 which means it has been heavily polluted. Source of pollution that enters to the Station 3 is diverse, such as from factory waste dominated by textile mills, from domestic waste because close to residential settlements, from agricultural waste and fisheries, and also because it is surrounded by many rice terraces and cultivation pools belong to the local community. The Station 4 has index diversity value with a range of 0.52-0.91, this value is the lowest appeal of all stations. This station has been heavily polluted because it got an accumulation of waste from upstream to downstream, also there are 3 textile industries, agriculture, and community settlement around Station 4.

3.2. Physical and chemical parameters of Citarik River

Physical parameters of waters were observed in this study which consists of temperature, current speed, brightness, and Total Suspended Solid (TSS). The results of the measurement of physical parameters can be seen in table 3.

| No. | Physical Parameter of Water | Research stations |
|-----|----------------------------|-------------------|
|     |                            | 1                 | 2                 | 3                 | 4                 |
| 1   | Water Current (m / s)      | 0.71 to 1.49      | 0.22 to 0.48      | 0.2 to 0.65       | 0.26 to 0.45      |
| 2   | Transparency (cm)          | 48-53             | 5-12              | 3-8               | 3-8               |
| 3   | Temperature (°C)           | 19 to 21.2        | 22-25             | 21.8 to 25        | 24.1 to 26.6      |
| 4   | TSS (mg / L)               | 12-24             | 50-66             | 17-83             | 39-121            |

The current in the Citarik River was in range from 0.2-1.49 m/sec. The lowest current speed was at Station 3 with a value of 0.2 m/s. It is located at the crowded area of the population, agriculture, livestock, and factories. Many garbage in the river retained water flow and increase sedimentation, therefore the river depth gets shallower. The highest current speed is at Station 1 which is 1.49 m/s. Station 1 is located on the upstream which far away from the residential settlements, therefore human activities, sedimentation, and garbage were not found. The speed of currents and water discharge is influenced by topography, sedimentation, rainfall, and other garbage or things in water flow [20].

The lower transparency was found at Stations 3 and 4 that was influenced by the accumulation of particles and some pollutants from the upstream hence blocking the penetration of light entering into the waters. At Station 1, there is no load of industrial and domestic pollutants that enter into the river, accordingly the water had high visibility and the transparency reach at least 40 cm. The transparency of light or brightness is the most important parameter in determining the productivity of water because it is closely related to the photosynthesis of algae and the Microphyta [2]. Indirect light, transparency affects the life of macrozoobenthos because it requires algae and macrophytes for its food source [16].

In this study, the temperature of Citarik River water was in the range from 19-26.6°C. The lowest temperature was observed in Station 1, which is located in the upstream. This lower temperature is probably due to the high density of vegetation alongside the river that may alter the light penetration. On the other hand, Station 4 had the highest water temperature. This station is located in the downstream of Citarik River, which is characterized by a low density of vegetation thus the light
penetration is very strong. Generally, the temperature in all stations was still in the tolerance range where macrozoobenthos can live and grow. This is supported by Rijjaludin et al [18] who reported that macrozoobenthos can survive and grow at the temperature between 35-40°C.

Turbidity can hinder light penetration to the water and decrease the transparency of water [11]. The lowest turbidity was observed at Station 1. The highest turbidity was at Station 4, which caused by many pollutants from industrial and domestic waste in this river water. The maximum turbidity limit for the life of water biota is 30 mg/L [14]. The water turbidity value of Citarik River which is still below of the maximum limit was only at Station 1. The lower the water turbidity, the greater the chance of vegetation to perform photosynthesis, the greater the supply of oxygen in water [1].

| Chemical Parameters | Research Station |
|---------------------|-----------------|
| DO (mg/L)           | 1               |
| BOD (mg/L)          | 2               |
| pH                  | 3               |

| No. | Research Station |
|-----|-----------------|
| 1   | DO (mg/L)       |
| 2   | BOD (mg/L)      |
| 3   | pH              |

The lowest concentration of DO was observed at Station 4 and the highest concentration of DO was at Station 1 as shown in Table 4. The lowest concentration at station 4 was 2.4 mg/L. Some factors that affect the DO level in the river waters are the diffusion of oxygen and the current velocity. Station 1 has a rapid current that make a high concentration of DO. But Station 3 and 4 has a slow currents water made low DO. According to Schmidt and Ferguson [19], a good range of DO for biota life is above 6 mg/L. Only Station 1 has a good DO value to support the life of aquatic biota in particular macrozoobenthos. Station 2 has a moderate concentration of DO, and the stations 3 and 4 have a critical value of DO concentrations. Low concentration of DO causes the difficulty of macrozoobenthos to grow even cause death.

According to Mays [9], BOD is a measure of oxygen amount used by microbes in water and can show the concentration of organic matter contained in the waters [9]. The water quality criteria based on the BOD is divided to four categories as follow: < 3 ppm is unpolluted, 3 – 4 ppm is mild polluted, 4.9 – 15 ppm is contaminated, and > 15 ppm is heavily polluted [11]. The BOD value in the Citarik River has a range of 0.32-6.4 mg/L. The lowest BOD was found at Station 1 in the upstream segment and the highest BOD was 6.4 mg/L at the Station 4 downstream segment. The water in the Station 1 was indicated as not polluted due to the BOD value of < 3 ppm. The Station 2 and 3 show a BOD values more than 3 ppm which means these stations were lightly polluted.

pH has a major influence on the life of aquatic biota, therefore the pH is often used as a measure of good or bad water as a living environment [12]. Citarik River has pH in the range of 6.5-8.8. The lowest one was observed at Station 1 and the highest was at Station 4. The degree of acidity is influenced by various factors such as organic and inorganic substances that enter into the water and others. According to Effendie [3], most aquatic biota is very sensitive to pH changes and likes pH with a value of 7-8.5. The lowest pH was observed at Station 1 with the pH range of 6.5-7.4. The value of 6.5 is only obtained when the first sampling because of higher rainfall in the upstream area, as well known the rainwater is generally acidic it will affect the pH of the water. The pH value of the Station 1 is good enough for the life of aquatic biota, shown with the high diversity of macrozoobenthos. Station 4 has a high pH of 8.8 due to effluent discharge from a textile factory which generally the substance is alkaline and thus affects the rise of pH. At Stations 2, 3, and 4, the pH values are less supportive for aquatic biota that is shown with a low diversity of macrozoobenthos.
4. Conclusion
Based on the diversity index of macrozoobenthos, the pollution status of Citarik River could be determined as follow, Station 1 was in unpolluted category, Station 2 was in medium polluted category, and Station 3 and Station 4 were in heavily polluted category. The pollution status of Citarik River is already confirmed. Thus, the river management should be made more intensive and periodic research needs to be conducted.

5. References
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