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Macroinvertebrate Diversity as Bioindicator of Water Quality in Anggoeya River, Kendari City

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A B S T R A C T

Anthropogenic activities will affect the quality of river water and the living things in it, including macroinvertebrates. Anggoeya River is one of the rivers that water source is used as raw water for PDAM Kendari, so its quality needs to be considered. The purpose of this study was to analyze the water quality of Anggoeya River using macroinvertebrate bioindicators and the relationship between macroinvertebrates and physicochemical parameters of water and substrate of Anggoeya River. Physico-chemical parameters consist of temperature, current velocity, TSS, turbidity, pH, COD, BOD, DO, substrate pH, and substrate type. The sampling technique used purposive sampling, where macroinvertebrate sampling was carried out at three points at each station three times repetitions, namely on the left, middle, and right sides of the river, based on the type of river habitat, namely pool, riffle, and rapid. Top of Form The results obtained for the highest diversity value is at Station I with a value of 1.99 and the highest dominance value is at Station III with a value of 0.98. As for the best FBI value of the three stations, namely at Station II with a value of 5.43 with a moderate organic matter pollution category. For the results of physicochemical parameters, some of which do not meet or exceed the Quality Standards based on Government Regulation Number 22 of 2021, namely TSS at Station III, BOD at Station I and Station II, and DO at Station III. The results of the macroinvertebrate diversity index relationship with physicochemical parameters has a strong to very strong relationship.

INTRODUCTION

Water resources are very important natural resources that are used continuously for the survival of humans and all living things, so the availability of safe water resources both in quality and quantity is needed to maintain the sustainability of resource utilization, especially river water (Rustiasih et al., 2018). The river is one of the containers where water gathers from an area that is intended for human activities, these activities result in the flow of river water into the river being polluted and resulting in a decrease in water quality (Yogafanny, 2015).

Anggoeya River is one of the rivers located in Kendari City. The Anggoeya watershed has an area of 898.45 hectares. There is Anggoeya spring which is used as a source of Raw Water for PDAM Kendari with potential water resources that can be available throughout the year which flows through the Anggoeya River. Land use in the Anggoeya watershed is forest covering 21.50 hectares, shrubs covering 9.31 hectares, settlements covering 52.75 hectares, and mixed agriculture covering 756.40 hectares (BPDAS Sampara, 2023). The land use in the Anggoeya watershed indicates significant deforestation and conversion of forested areas into settlements and agricultural lands. This can lead to increased sedimentation, erosion, and loss of habitat diversity, affecting the overall health of the river ecosystem. The presence of settlements and mixed agriculture in the watershed suggests potential sources of pollution such as domestic sewage, agricultural runoff containing fertilizers and pesticides, and solid waste disposal. These pollutants can degrade water quality and harm aquatic life in the Anggoeya River.

The Anggoeya Spring supplies raw water to PDAM Kendari, but deforestation, land use changes, and pollution threaten its quality and quantity, impacting water reliability and safety. Shrubs and forested areas in the watershed provide crucial habitats, but conversion to settlements and agriculture leads to habitat degradation and biodiversity loss, disrupting the ecological balance of the Anggoeya River. Various human activities, including industrial discharges, agricultural runoff, urbanization, improper waste disposal, sewage discharge, construction, and deforestation, contribute to river waste, causing pollution and environmental degradation. This waste introduces pollutants like heavy metals and pesticides, harming aquatic organisms, and altering water pH and oxygen levels. Discharged waste decreases river water quality, impacting organisms such as macroinvertebrates.

Macroinvertebrates are invertebrate organisms whose habitat is in rivers, usually living attached to water and mud (Kalih et al.,2018). Macroinvertebrates are very sensitive to environmental changes, so the species found in the water can be analyzed to provide an overview of the condition of the waters. Macroinvertebrates can be used as biological indicators because of their habitat preference factors and also their relatively low mobility so their existence is very directly influenced by all materials that enter the environment land waters (Rustiasih et al., 2018). Macroinvertebrates have an important role in maintaining systems in ecosystems, especially aquatic ecosystems because macroinvertebrates have functioned as first-level consumers (phytoplankton predators), second-level consumers (zooplankton predators) in the food chain and also as balancer nutrients in the aquatic environment (Riry et al., 2020).

Macroinvertebrate diversity is very dependent on tolerance and level of sensitivity to environmental conditions. Water quality monitoring which is usually done through the analysis of physical and chemical properties of water is sometimes difficult to rely on because pollutants are so quickly dissolved in water and lost to the estuary river. This thing that encourages the biological monitoring system where aquatic macroinvertebrates as a biological indicator monitoring tool (Maruru, 2012 in Rustiasih et al., 2018), In addition, Carter and Resh (2001) noted that macroinvertebrates are sensitive to changes in water quality, making them effective indicators of environmental conditions. They inhabit aquatic ecosystems for extended periods, reflecting cumulative effects over time. Monitoring their diversity provides insights into ecosystem health. Macroinvertebrates play crucial roles in aquatic food webs and nutrient cycling. Changes in their populations can indicate disruptions to ecosystem functioning due to pollution or habitat degradation (Carter and Resh, 2001). Based on the above description, it is considered important to conduct research on the diversity of aquatic macroinvertebrates as bioindicators of the water quality of Anggoeya River in Kendari City.

METHODS

Location and Time

This research was conducted in Anggoeya River Kendari and analysis samples were collected at the Integrated Laboratory of University. The sampling locations were purposefully determined at three points, namely Station I, Station II, and Station III, representing the upstream, middle, and downstream areas of the Anggoeya River, respectively. The coordinate point of Station I is 04°01'21.56"S122°34'27.15" E, the coordinate point of Station II is 4°00'22.9"S122°33'54.2" E, and the coordinate point of Station III is 4°02'31.4 "S 122°33'51.2 "E (Figure 1). This research was conducted in August-September 2023.

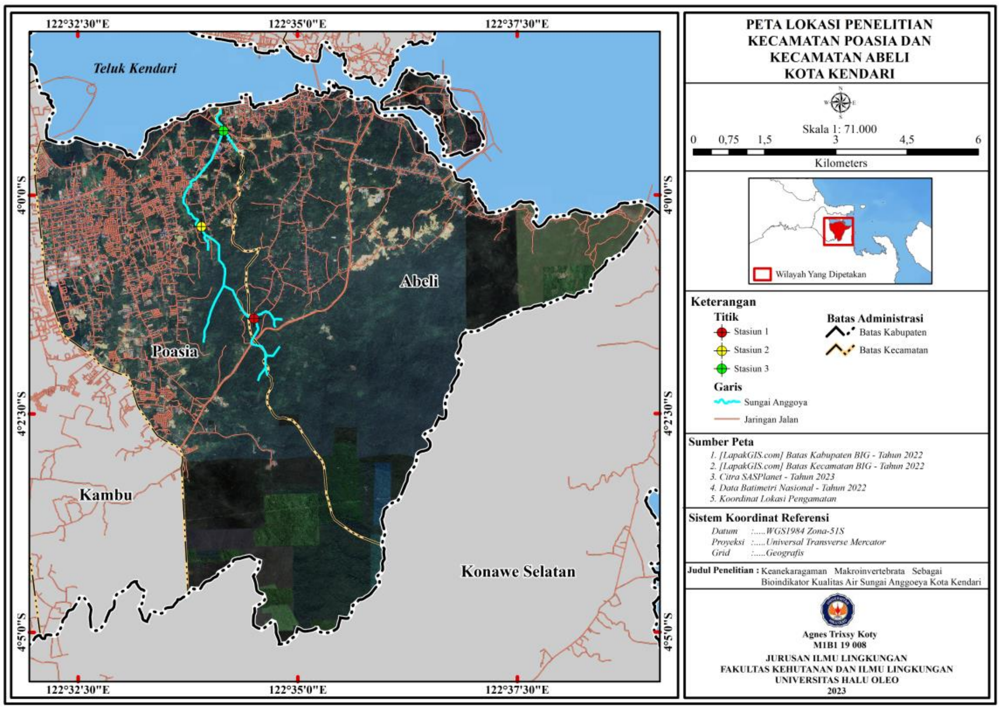

Fig.1.Research location map

Method of Collecting Data

Water sampling is done before taking macroinvertebrate samples. Water sampling was carried out at three points at each station (three repetitions), namely on the left, center, and right side of the river. Water samples are then combined at each station point into a sample container. After that, label the time(hour, date, month, year) and place of sampling on the sample container. The water samples that have been taken are taken to the Integrated Laboratory of Halu Oleo University to be analyzed based on pre-determined parameters, namely COD (Chemical Oxygen Demand, BOD (Biochemical OxygenDeman), DO (Dissolved Oxygen, turbidity, and TSS (Total Suspended Solid) then compared with class II water quality standards which have been determined by government regulation no 22 of 2021, namely not exceeding 25 for COD parameters, 3 for BOD parameters and 50 for TSS parameters. (Government Regulation Number 22 of 2021). Measurement of current velocity, temperature, and pH of water is done directly in the field. The current speed is calculated using a stopwatch and a plastic pumping ball. Temperature measurements were taken using a thermometer by inserting the thermometer into the water for 1-2 minutes and reading the temperature as soon as the thermometer was removed from the water (Rahayu et al., 2009). Measurement of water pH using a pH meter. Sampling the substrate using a paralon pipe with a high 10 cm and 7.5cm in diameter. Paralon pipes were immersed 10 cm deep at one point each at each station. Substrate samples that have been obtained using pipes are put into plastic clips and taken to the Integrated Laboratory of Halu Oleo University to identify the type of sediment.

Macroinvertebrate sampling was carried out at three points at each station, sampling was carried out three times, namely on the left, middle, and right sides of the river based on the type of river habitat, namely pool riffle and rapid. Macroinvertebrate sampling using a net with a mesh size of 500 µm. The type of net used to take macroinvertebrate samples is a surber sampler. Surber samplers are used to take macroinvertebrate samples in rivers where the riverbed is rocky, and gravelly and the flow is fast. To capture macroinvertebrates, the front of the net is placed facing opposite the direction of the river current and enters the substrate ± 10 cm (Rahayu et al.,2009). Samples were then placed into a tray to separate the macroinvertebrates trapped in the suber net cleaned using distilled water and put into a sample container that has been labeled and preserved using 70% alcohol until all samples are submerged. Macroinvertebrate samples are subsequently identified by matching their morphological characteristics with those described in a macroinvertebrate identification guidebook, enabling classification up to the family level. The identification books used were water monitoring in watersheds (Rahayu et al., 2009), methods in stream ecology (Hauer and Gary, 2007) and guides to aquatic macroinvertebrates of the upper Midwest waters (Bounchard, 2004).

Data Analysis

Diversity Index

The diversity index (H') describes the state of a population of organisms mathematically to make it easier to analyze information on the number of individuals of each species in a community. For that done calculation using the equation of Shannon-Wiener (Krebs, 1989 in Kusumaning sari et al., 2015). The diversity index (H') uses the Shannon-Wiener formula:

$$H' = \sum_{i=1}^{n} (pi)(\ln pi)$$

Description:

H' = Species diversity index

Pi = Number of individuals each type (I=1,2,3,…n) where $Pi = \frac{ni}{N}$

ni = Number of individuals of each species

N = Total number of individuals diversity index describes diversity, pressure on ecosystems, productivity, and ecosystem stability.

The diversity index criteria (H') used are in Table 1. Lee *et al* (1978) *in* Sagala (2013) provide criteria for water quality conditions based on the diversity index value listed in Table 2.

Table1. Diversity index criteria

Diversity Index (H')	Level Diversity	Description
H'<1,0	Low	Low diversity, poor, very low productivity as an indication of heavy pressure and unstable ecosystems.
1,0<H'<3,32	Medium	Diversity moderate, productivity sufficient, ecosystem conditions moderately balanced, pressure moderate psychological.
H'>3,32	High	High diversity, good ecosystem stability, hight productivity, resilien to ecological stress.

Source:*Wardoyo (1989) in Rustiasih et al (2018)*

Table2. Classification of pollution degree based on diversity index

No.	Degree of Pollution	Diversity Index
1	Not yet polluted	>2,0
2	Lightly polluted	1,6-2,0
3	Moderately polluted	1,0-1,5
4	Heavily polluted	<1,0

Source: *Leeetal (1978)in Sagala(2013)*

Dominance Index

The dominance of a species in the community can be known from the results of the analysis using Simpson's dominance index which has a criterion value (Table 3) which is expressed as follows (Odum,1994 *in* Ambeng *et al.*,2023):

$$C = \sum\left(\frac{ni}{N}\right)^2$$

Description:

C = Simpson's dominance index

ni = Number of individuals of each species

N = Number of individuals of all species

Table3. Criteria for Dominance Index

Dominance Index	Dominance Level
D<0,4	Low
0,4<D<0,6	Medium
D>0,6	High

Source:Legendre,1983 in Sidik et al.,2016

Family Biotic Index (FBI)

The Family Biotic Index (FBI) was developed by Hilsenhoff (1988) based on the tolerance value (resistance to environmental changes) of each family and the classification of water quality based on the family biotic index in Table 4. The formula used in the calculation of FBI is as follows (Widiyanto and Ani., 2016):

$$FBI = \sum_{i-1}^{1=n} \frac{xi.\,ti}{N}$$

Description:

FBI = macroinvertebrate index value

i = order of family groups that make up the macroinvertebrate community

xi = number of individuals of the i-th family group

ti = tolerance level of the i-th family group

N = total number of individuals found in the sample

Table 4. Classification of water quality based on family biotic index (FBI)

Family Biotic Index	Water Quality	Organic Pollution Level
0,00-3,75	Very good (Excellent)	Not contaminated with organic matter (Organic pollution unlikely)
3,76-4,25	Very Good	Slightly polluted with organic matter (Possible slight organic pollution)
4,26 -5,00	Good	Possibly slightly polluted (Some organic pollution probable)
5,01 -5,75	Medium (fair)	Moderately polluted (fairly substantial pollution likely)
5,76 -6,50	Somewhat bad (Fairly poor)	Moderately heavily polluted (substantial pollution likely)
6,51 -7,25	Poor	Heavily polluted (very substantial pollution likely)
7,26 -10,00	Very bad (very poor)	Very heavily polluted (Serve organic pollution likely)

Source:Hilsenhoff,1988

Analysis of Physico-Chemical Parameters

The physicochemical parameters that will be analyzed are water pH, substrate pH, substrate texture, COD, BOD, DO, temperature, turbidity, TSS, and current speed. Measurement of physicochemical parameters such as water pH, substrate pH, temperature, and current speed will be measured directly at the research location, and for substrate texture parameters, COD, BOD, DO, turbidity and TSS will be measured in the Halu Oleo University Integrated Laboratory and will be compared with standards Class II water quality by Government Regulation Number 22 of 2021.

Correlation Analysis Pearson

Pearson correlation analysis is a form of the formula used to find the relationship between the dependent variable and the independent variable and also to categorize the level of relationship between macroinvertebrates and physicochemical factors. The Pearson correlation analysis formula (Walope,1990 *in* Dewianti *et al.*,2018) is found in the equation bellow.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Description:

R = pearson correlation coefficient
X = independent variable: chemical physical parameters
Y = dependent variable: macroinvertebrate diversity

RESULTS AND DISCUSSION

Macroinvetebrate Community Structure

Based on the results of research conducted in Anggoeya River at Station I, Station II, and Station III, 9 orders were obtained with 13 families of macroinvertebrates shown in Table 5. In Table 5, 25 families of macroinvertebrates were found at Station I, 14 families of macroinvertebrates at Station II, and 185 families at Station II. Macroinvertebrate family at station III. The total abundance of macroinvertebrate families obtained from the three stations is 224 macroinvertebrates.

Table 5. Macroinvertebrate abundance in Anggoeya River

No.	Order	Family	Station		
			I	II	III
1	Odonata	*Lestidae*	1	0	0
2		*Libellulidae*	7	0	0
3	Ephemeroptera	*Heptageniidae*	2	0	0
4		*Caenidae*	1	0	0
5		*Baetidae*	0	5	0
6	Trichoptera	*Limnephilidae*	1	0	0
7	Diptera	*Ceratopogonidae*	3	0	0
8		*Chironomidae*(red)	0	2	1
9	Sorbeocacha	*Thiaridae*	4	4	183
10	Hygrophila	*Physidae*	0	0	1
11	Annelida	*Oligochaeta*	4	1	0

12	Hemiptera	*Gerridae*	2	0	0
13	Amphipods	*Gammaridae*	0	2	0
	Total		25	14	185

Source: Analysis Data, 2023

Diversity Index

Based on the results macroinvertebrate identification, an analysis was carried out with the results of the diversity index shown in Table 6.

Tabel 6. Diversity index and degree of pollution based on macroinvertebrate diversity index in Anggoeya River

No.	Station	Index diversity (H')	Level diversity	Degrees pollution
1	I	1.99	Medium	Lightly polluted
2	II	1.47	Medium	Moderately polluted
3	III	0.07	Low	Heavily polluted

Source: Analysis Data, 2023

Station I has a diversity index of 1.99, Station II has a diversity index of 1.47, and Station III has a diversity index of 0.07. Station I and Station II have a moderate level of diversity with sufficient productivity, balanced ecosystem conditions, and moderate ecological pressure. Station III has a low level of diversity with low diversity, poor, very low productivity as an indication of heavy pressure and unstable ecosystems (Wardoyo,1989, Rustiasih et al., 2018). The high macroinvertebrate diversity index at Station I is thought to be due to more riparian plants at Station I compared to Station II and Station III. The low value of macroinvertebrate diversity at Station III in addition to the little riparian vegetation, Station III is located downstream which receives more influence from anthropogenic activities. Based on the classification of the degree of pollution using the diversity index value, Station I is classified as mildly polluted. Station II is classified as a degree of lightly polluted pollution and Station III is classified in the degree of pollution heavily polluted.

Dominance Index

Based on the results macroinvertebrate identification, an analysis was carried out index dominance with result shown inTable 7.

Table7. Macroinvertebrate dominance index in Anggoeya River

No.	Station	Dominance Index (C)	Dominance Level
1	I	0.16	Low
2	II	0.26	Low
3	III	0.98	High

Source: Analysis Data, 2023

The dominance index at Station I and Station II has a low dominance level where the dominance index value of Station I is 0.16 and the dominance index of Station II is 0.26. While the dominance index of Station III has a high dominance level with a value of 0.98. Station III shows a comparison of the number of specimens between the Thiaridae family which has 183 specimens while the chironomidae and Physidae families only have 1 species each. The number of Thiaridae family in Station III is because it includes macroinvertebrates that are resistant to pollution. This is supported by Setiawan(2009) in Rustiasih et al (2018) who state that the Thiaridae family has excellent adaptability in various substrates and has a high ability to accumulate polluted materials without being killed because it hides in its shell. It is also suspected that the occurrence of dominance at Station III is because it is in the estuarine area. The dominance value of each station where the downstream dominance index is higher. The high and low values of the macroinvertebrate dominance index in Anggoeya River are in separable from anthropogenic activities that affect the health of the river, which supports the lives of living things, including macroinvertebrates.

Family Biotic Index (FBI)

The family biotic index is a water quality index calculation developed by Hilsenhoff (1988) based on the tolerance value (resistance to environmental changes) of each family. According to Arisandi (2012) in Widiyanto and Ani (2016), the calculation of benthic macroinvertebrate biotic index values with the Modified Family Biotic Index has been widely used to identify the level of organic pollution in waters, where each macroinvertebrate family has a certain score that indicates the level of tolerance to organic pollution. The results of the FBI analysis are listed in Table 8.

Table8. Macroinvertebrate Family Biotic Index values at 3 stations

No.	Station	FBI Value	Water Quality Category	Organic pollution level
1	I	6.44	Somewhat bad	Moderately heavily polluted
2	II	5.43	Medium	Moderately polluted
3	III	6.02	Somewhat bad	Moderately heavily polluted

Source: Analysis Data, 2023

Based on the results of the FBI analysis in Table 8, Station I has an FBI value of highest with a value of 6.44 where the water quality is in the rather poor category with an organic pollution level that is moderately polluted. Station II has the lowest FBI value with a value of 5.43 where the water quality is in the medium category with a moderate level of organic pollution. Station III has an FBI value of 6.02 where the water quality is in a rather poor category with a rather heavy level of organic pollution.

The high value of the family biotic index at Station I even though it is located in the upper reaches of the river. However, land use around Station I occurs plantation activities as well as the presence of livestock, and around the river, there is also land clearing which results in plant degradation around Station I which also affects macroinvertebrate life.

Based on the research results from the three stations, there are macroinvertebrates found with the highest tolerance value (ti), namely the Libellulidae family with a tolerance value of 9, Lestidae with a tolerance value of 9, Oligochaeta with a tolerance value of 8, Gerridae with a tolerance value of 8, Chironomidae (red) with a tolerance value of 8, Oligochaeta with a tolerance value of 8 and Physidae with a tolerance value of 8. These types of macroinvertebrate families have high tolerance values, which means that these family types have properties that are more tolerant of environmental changes compared to family groups that have low tolerance values. The EPT group (Ephemeroptera, Plecoptera, and Trichopter) is a group of biota that is sensitive to pollution (Susanti and Rahardyan., 2017). The existence of this EPT is one of the bioindicators of water quality that is Good. According to Young et al., 2014; Lewin et al., 2015 in Kahirun et al., 2019 it is said that this EPT group is very sensitive to pollutants, so when this type of macroinvertebrate is found in water, the waters can be said to be unpolluted. In the results of the study, there are sensitive families such as Heptagenidae and Baetidae whose tolerance value is 4 included in the Ephemeroptera order, and Limnephilidae tolerance value is 4 included in the Trichoptera order. However, it was not found in the order Plecoptera. The family that also has a low tolerance value is Gammaridae which is included in the Amphipoda order with a tolerance value of 4. Jerves et al., 2017 in Hellen et al., 2020 said that if the number of EPT populations decreases and organisms that are tolerant of pollution are also found, it is characteristic of pollution.

Water Quality of Anggoeya River Based on Physics-Chemistry Parameters

In this study, the measurement of physical and chemical parameters is divided into two, namely direct data collection and data collection in the form of samples for laboratory testing. Water sampling for measurement of physical and chemical parameters was carried out just before macroinvertebrate sampling. Data collection of physicochemical parameters in this study are temperature, current velocity, TSS, turbidity, pH, COD, BOD, DO, substrate pH, and substrate type.

The values of the physico-chemical parameters obtained were compared based on the quality standards of class II of Government Regulation number 22 of 2001 listed in Table 9.

Table 9.Physico-chemical parameters of water and substrate in Anggoeya River

No.	Parameter	Unit	Stat			Class II Quality Standards PP No.22 of 2021
			I	II	III	
1	Temperature	^0C	28,9	28,9	29,4	Dev3
2	Current speed	m/s	0,45	0,15	0,04	-
3	TSS (mg/L)	mg/L	32	40	80	50mg/L
4	Turbidity	NTU	0,58	0,66	0,66	-
5	pH	-	7,7	7,9	7,4	6-9
6	COD	mg/L	1,92	3,52	3,84	25mg/L
7	BOD	mg/L	8,02	5,45	2,68	3mg/L
8	DO	mg/L	8,17	7,5	3,41	≥4 mg/L

9	pH of Substrate	-	5,84	6,77	6,82	-
10	Substrate type	-	Medium and sandy smooth	Medium and sandysmoot h	Medium and sandy smooth	-

Source: Analysis Data, 2023

The results of temperature measurements in Anggoeya River found that the highest temperature was at Station III (land use of mixed gardens and forests), namely 29.4. While Station I and Station II have the same temperature (residential land use), namely 28.9. Vegetation at Station I and Station II covers more of the river surface from direct sunlight than at Station III. The temperature measurement results obtained are in line with the opinion of Khairul (2017), namely that the temperature of the waters is influenced by the intensity of sunlight, and the factor of tree cover (canopy) of the vegetation that grows around it. Also, another cause is that the more downstream the temperature increases due to an increase in the decomposition of organic substances in microbes (Effendi, 2003).

Current speed is important in the spread of organisms. According to Barus (2004) in Irawan et al (2017) states that current velocity plays an important role in the spread of aquatic organisms. Based on the measurement of current velocity, Station I has a current velocity of around 0.45 m/s, Station II has a current velocity of around 0.15 m/s and Station III has a current velocity of around 0.04m/s. Based on the observation of current velocity For each station in Anggoeya River, the speed of the current decreased further downstream. This is in line with Silfana (2009) in Rahman (2017) which states that the more downstream the area, the slower the water movement will be. The TSS value of Station I is the lowest compared to Station II and Station III because the substrate at Station I is small rocks and the current speed is higher than Station II and Station III. The highest TSS is found at Station III because of the large number of anthropogenic activities that are carried into waterbody characterized by the amount of garbage and the type of substrate is fine sand. This is in line with the opinion (Djoharam et al., 2018) that TSS consists of mud, fine sand, and microorganisms caused by soil erosion or soil erosion that are carried into water bodies.

The turbidity value at Station I was 0.58 NTU, Station II was 0.66 NTU and Station III was 0.66 Turbidity usually indicates the level of water clarity or turbidity of water flow caused by sediment load elements, either mineral or organic (Asdak, 2004). Turbidity of Station II and Station III have the same value. This is thought to be because the TSS at Station III has been deposited with the substrate due to the very slow current speed.Station I has a pH of 7.7and Station II has a pH of 7.9 and Station III has a pH of 7.4. The lowest pH value is found at Station I and the highest pH value is found at Station II. The pH number 7 is a neutral pH. According to (Brook et al., 1989 in Asdak, 2004) pH 6.5-8.2 is the optimum condition for living things.

The COD value at Station I is 1.92 mg/L, Station II is 3.52 and Station III is 3.84 mg/L. The concentration of COD from upstream to downstream tends to increase. The high concentration of COD is related to the presence of organic matter in water sourced from high-density residential areas. According to Effendi (2003), Chemical Oxygen Demand (COD) describes the total oxygen required to chemically oxidize organic matter, both those that can be degraded biologically (biodegradable) and those that are difficult to degrade biologically (non-biodegradable) into CO2 and H2O so that all kinds of organic matter, both those that are easily decomposed and those that are difficult to decompose will be oxidized.

The highest BOD value is found at Station I with a value of 8.02 and the lowest value is found at Station III with a value of 2.68 mg/L. The BOD value does not indicate the actual amount of organic matter, but only measures the amount of oxygen needed to decompose the organic matter or is also interpreted as a description of the amount of easily decomposed organic matter contained in wastewater (Dameanti et al., 2022). Lee et al (1978) in Khairul (2017) explained that the level of pollution of a water body can be assessed based on the content of BOD values where 5.1-14.9 are moderately polluted waters. Based on the results, Station I and Station II BOD values indicate the waters are moderately polluted.

Too high and too low dissolved oxygen levels will endanger the life of organisms in the water and affect water quality (Harish et al., 2020). Based on the research results, the DO value at Station I was 8.27 mg/l, Station II was 7.5 and Station III was 3.41. Based on the class II standard of PP No.22 of 2021, Station III does not meet the quality standards, whereas Do station II I≤4 mg/l. The pH of the substrate is different for each station. Station I has a pH of 5.84 Station II has a pH of 6.77 and Station III has a pH of 6.82. According to Baker et al (1990) in Effendi (2003), the effect of pH at values of 5.5-6.0, namely total abundance, biomass, and productivity, has not undergone significant changes. The pH value of 6.0-6.5 influences plankton and benthic diversity slightly decreased and total abundance, biomass, and productivity did not change.

Stations I, II, and III have the same substrate type which is dominated by medium sand and very fine sand. Substrate type affects macroinvertebrate life. This is the opinion of Gething et al., 2020 in Kahirun et al., 2023 who stated that the adaptation of macroinvertebrates to environmental conditions such as hard substrates is different from macroinvertebrates living in fine substrates. The bottom substrate is closely related to the fraction of sediment grains. If the current speed is strong, there will be many sandy substrates because only large particles settle faster than smaller particles (Taqwa et al., 2014).

Relationship between Diversityof Macroinvertebrates with Physics-Chemical Parameters in Anggoeya River

To determine the relationship between the diversity index and parameters The Pearson Correlation formula was used to analyze the physico-chemical properties of water and substrate in Anggoeya River. Data obtained from analysis using SPSS 29. The correlation results can be seen in Table 10.

Table 10. Relationship between macroinvertebrate diversity index and physico-chemical parameters

No.	Parameters	Correlationvalue	Relationship Level
1.	Temperature	-0,985	Very strong
2.	Current Speed	0.842	Very strong
3.	TSS	-0.998	Very strong
4.	Turbidity	-0.643	Strong
5.	pH of Water	0,858	Very strong
6.	COD	-0,735	Strong
7.	BOD	0,980	Very strong
8.	DO	0,997	Very strong
9.	pH of Substrate	-0,678	Strong

Source:Analysis Data,2023

Based on Pearson correlation, the correlation between temperature and biodiversity index is -0.985, indicating a very strength classification level because the correlation value falls within the coefficient interval of 0.80-1.00. While the direction of the correlation (-) indicates that the correlation is inversely proportional which means that the higher the temperature the lower the macroinvertebrate diversity. According to (Satriarti et al., 2018) the impact caused by an increase in temperature is in the form of a decrease in the amount of dissolved oxygen, an increase in chemical reactions, which will result in a decrease in the life activities of aquatic organisms. Sastrawijaya (2009) said that each species has its optimum temperature. So that if the water temperature increases, only certain species can survive that have a higher optimum temperature.

The correlation of current speed with the diversity index is 0.842 which means it has a very strong correlation because it is included in the coefficient interval 0.80-1.00. While the direction of the correlation (+) which has a unidirectional correlation, meaning that the faster the current, the higher the diversity index. Current speed is very important in the spread of a organisms. The currentspeed in a body of water will determine the distribution pattern of organisms that live in the waterbody. According to Barus (2004) in Irawan et al. (2017) stated that current speed plays an important role in the spread of aquatic organisms, dissolved gases and minerals contained in water.

The TSS correlation with the macroinvertebrate diversity index is - 0.998 which means it has a very strong correlation because it is in the coefficient interval 0.80-1.00. As for the direction of the relationship, it is marked (-) which means that when the TSS value increases, the index valuemacroinvertebrate diversity decreases. Thisis in line with the opinion of (Yulianti, 2019) which says that high TSS levels in river water will cause the river water to become turbid which can result in a decrease in oxygen which affects organism.

The correlation between turbidity and macroinvertebrate diversity index is -0.643. When viewed from the coefficient interval value, the relationship is strong because it is in the coefficient interval value of0.60-0.799. While for The direction of the relationship is opposite because it is marked (-) which means that if turbidity increases, the value of the diversity index decreases. This is in line with the opinion of Lloyd (1985) in Effendi (2003) that an increase in turbidity values in shallow and clearwaters by 25 NTU can reduce13%-50% of primary productivity.

The correlation of water pH with the diversity index is 0.782 which means it has a strong relationship because it is included in the coefficient interval of 0.60.-0,799. As for the direction of the relationship, it is marked (+), which means that if the pH of the substrate increases, the diversity of macroinvertebrates in the Anggoeya River also increases.

The correlation between COD and diversity index is -0.735 which meansit has a strong relationship because it is in the coefficient interval of 0.60 - 0.799. Meanwhile, when viewed from its direction, it is inversely proportional because it has a sign (-) which means that if the COD value increases, the value of the macroinvertebrate diversity index in the Anggoeya River decreases. This is in line with the opinion of Naillah et al (2021) who say that high concentrations of COD indicate the greater the level of pollution that occurs in a body of water.

The correlation of BOD with the diversity index is 0.980 which means it has a very strong relationship because it is in the coefficient interval of 0.80-1.00. Meanwhile, if you look at the direction, it is inversely proportional because it has a sign (+) which means that if the BOD value increases, the macroinvertebrate diversity index increases. The correlation of DO with the diversity index is 0.997 which means it has a very strong relationship because it is in the coefficient interval of 0.80 -1.00. Meanwhile, when viewed from its direction, it shows a strong relationship with DO. This is unidirectional because it has a (+) sign, which means that if the DO value increases, the macroinvertebrate diversity index in the Anggoeya River also increases. This is in line with the opinion of Fadzry et al (2020) which states that thegreater the dissolved oxygen, the smaller the degree of fouling. The presence of oxygen in the wateris very important for aquatic organisms because if the DO concentration in the water is low, it indicates the presence of high organic pollutants.

The correlation between substrate pH and macroinvertebrate diversity index is -0.678 which means it has a strong correlation. While the direction of the relationship is inversely proportional (-) which means that if the pH of the substrate increases then index macroinvertebrate diversity of Anggoeya River decreases.The amount of pH in a body of water can be used as an indicator of the balance of chemical elements and nutrients that are very beneficial for the life of aquatic vegetation (Rahayu et al., 2009).

CONCLUSIONS

Based on the research results obtained, it can be concluded as follows:

1. A total of 9 orders and 224 macroinvertebrate families were identified across the three stations. Diversity indices were calculated, indicating moderate to low levels of diversity across the stations, with Station I having the highest diversity and Station III the lowest. Dominance indices revealed low dominance at Stations I and II and high dominance at Station III, primarily due to the prevalence of the Thiaridae family. The Family Biotic Index (FBI) analysis indicated moderate to somewhat bad water quality across the stations, with moderately to moderately heavily polluted organic pollution levels.
2. The physicochemical parameters of the water and substrate were measured to assess water quality. Temperature, current speed, TSS, turbidity, pH, COD, BOD, DO, substrate pH, and substrate type were analyzed. The results showed variations in these parameters across the stations, with some exceeding the Class II quality standards. For example, Station III had the highest organic pollution level based on COD and BOD values and the lowest dissolved oxygen (DO) concentration.
3. Correlation analysis between macroinvertebrate diversity and physico-chemical parameters revealed strong relationships. Temperature, TSS, COD, and substrate pH showed inverse relationships with macroinvertebrate diversity, while current speed, pH of water, BOD, DO, and turbidity showed positive relationships. These findings suggest that changes in water quality parameters influence macroinvertebrate diversity in the Anggoeya River, highlighting the importance of monitoring and managing these parameters to maintain ecosystem health.

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