Eduvest – Journal of Universal Studies
Volume 3 Number 6, June, 2023
p- ISSN 2775-3735- e-ISSN 2775-3727

DETERMINATION OF CIKAPUNDUNG RIVER WATER QUALITY INDEX USING IKA-INA METHOD AND POLLUTION INDEX

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ABSTRACT

The Cikapundung River which crosses the city of Bandung is widely used for various purposes including as a drainage, tourist attraction and raw material for drinking water. In fact, the Cikapundung River is inseparable from environmental pollution, both from domestic waste around the river flow and industrial waste which ultimately has an impact on decreasing water quality. This research aims to to get an overview of the water quality condi-tions of the Cikapundung river which were assessed using Index IKA-INA method. To see how big the impact is on water quality in the Cikapundung River, a water quality index is used, which is a method for assessing the condition of a body of water based on selected parameters. Sampling was carried out at 3 sites during the dry and rainy seasons. Then the water quality criteria are determined using the National Sanitation's Foundation (NSF-WQI) method which has been modified to become the IKA-INA method and Pollution Index (IP) based on Minister of Environment Regulation No. 115 of 2003 concerning guidelines for determining water quality status. The results of the analysis using the IKA-INA method, the water quality of the Cikapundung River is generally in the "moderate" category, only one site is included in the "good enough" category, while the determination of water quality status using the Pollution Index method is included in the "fair" category. Moderately Polluted" for all sites both during the dry and rainy seasons with IP values ranging from 1.36 to 4.38.

KEYWORDS *water quality; pollution index; Cikapundung River*

How to cite: Artiningrum, T. & Saeful, N. S. (2023). Determination of Cikapundung River Water Quality Index Using IKA-INA Method and Pollution Index. *Journal Eduvest. 3* (6): 1086-1097
E-ISSN: 2775-3727
Published by: https://greenpublisher.id/

INTRODUCTION

Water is a natural resource that is very important for life on earth. Regular monitoring of water quality for water sources is necessary to determine whether the quality of the water is still in accordance with the applicable quality standards (Hanisa et al., 2017). Fresh water, is a natural resource that is increasingly threatened, especially due to anthropogenic influences such as population growth, unmanaged industrialization and accelerated urbanization and other things that are directly caused by human activities (Nasution, 2021). As knowledge increases about the importance of water, especially fresh water for humans and aquatic life, the need to understand water quality also increases (Zahara, 2018). Many ecologists and environmental scientists are trying to find solutions to global environmental problems, including pollution and environmental pollution, ecosystem health and climate change. A variety of different methods have been developed and applied to characterize water quality, monitor data and apply assessment methods using indices.

The decline in water quality due to pollution in the Cikapundung River will affect many interests, including the availability of raw water. The Cikapundung River is one of 13 tributaries that empties into the Citarum River, flowing across three urban regencies, namely Bandung City, Bandung Regency and West Bandung Regency which cover 11 sub-districts. This 28-kilometer-long river empties into the Citarum River in Bale Endah (Bandung Regency) and is one of the 13 main tributaries that supply water to the Citarum River (Bappenas, 2022a).

Figure 1. Cikapundung River, seen from Jalan Asia Afrika

The Upper Cikapundung River is located in the Cigulung and Maribaya areas (West Bandung Regency), is a source of raw material for drinking water for residents of the city of Bandung, around 2700 liters of water per second is processed by PDAM Tirtawening Bandung City, part of which comes from the Cikapundung river (Bappenas, 2022b). It has an area of 111.3 km² upstream, 90.4 km² in the middle and 76.5 km² downstream. Most of the buildings that are settlements are directly on the banks of the river, around 1,058 houses are close to the riverbanks, almost all of which discharge waste directly into the river (Bappenas, 2022a).

This research was conducted to get an overview of the water quality conditions of the Cikapundung river which were assessed usingmethodIndexIKA-INA. This method is a modified method from the National Sanitation Foundation (Ministry of Environment and Forestry, 2019) and IndexThe pollutioncan be used as an assessment of the quality of a body of water, the suitability of the designation of a body of water and improvement of the quality of the body of water if there is a decrease in quality due to the presence of pollutant compounds (Ministry of Environment, 2003). Moreover, this research aims to to get an overview of the water quality condi-tions of the Cikapundung river which were assessed using Index IKA-INA method.

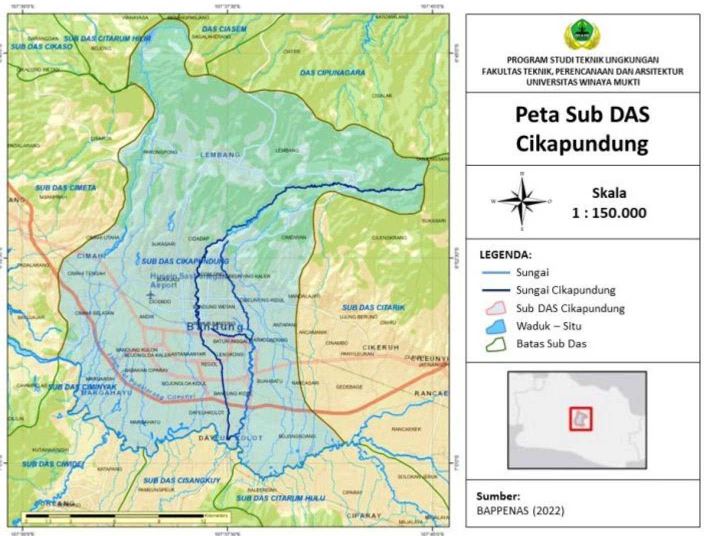

Figure 2. Map of the Cikapundung Watersheed in West Java

RESEARCH METHOD

Sampling Locations

This research begins with preparation, both literature preparation and the tools and materials used in the research. Sampling locations include 3 locations on the Cikapundung River which passes through the city of Bandung. Sampling was carried out during the rainy season, which is March 2022 and the dry rainy season in September 2022. Sampling was carried out at 3 locations, namely Site I which is located on Dago Pakar, Site 2 on Jalan Viaduct and Site 3 on Jalan Soekarno Hatta. The coordinates for taking the sample are presented in the table. 1

Table 1. Coordinates of the Sampling Places

Site	Coordinate
1	S 06o 51' 73.7" & E 107o 37' 25.1"
2	S 06o 54' 54.9" & E 107o 36' 26.4"
3	S 06o 56' 57.68" & E 107o 37' 18.53"

Sampling Technique

River water samples were taken at 10 am taking into account the high activity of domestic discharges. Sample testing was carried out at the PERUMDA Tirtawening Environmental Quality Control Laboratory (LPKL), Bandung City. Some of the parameters are tested directly on site to ensure the measured quality does not change significantly, such as temperature and dissolved oxygen levels. Tests carried out both in the field and in the laboratory on samples are carried out using instrumentation equipment and test methods that apply nationally and internationally such as the Indonesian National Standard (SNI), Standard Method and others, so as to produce a high level of accuracy in the test results. Table 2 shows the parameters tested and the reference method used.

Table 2. Parameter Measurement Reference Method

No.	PARAMETER	Reference Method
1	TDS	SNI 6989.27:2019
2	TSS	SNI 6989.3:2019
3	pH	SNI 6989.11:2019
4	BOD_5	SNI 6989.72:2019
5	COD	SNI 6989.2:2019
6	DO	SNI 06-6989.14-2004
7	Nitrates (NO3-N)	SNI 6989.79:2011
8	Ammonia (NH3-N)	SNI 6989.30:2005
9	TP	APHA 4500 PD-2017
10	Fecal Coliform	APHA 9222 B-2017

Determination of Water Quality Index

In 2018 the Center for Research and Development of Quality and Environmental Laboratory (P3KLL), the Research and Development Agency and Innovation of the Ministry of Environment and Forestry, developed a method for calculating the Water Quality Index (IKA) called the modified Indonesian Water Quality Index (IKA-INA) method, which is a modified method from National Sanitation. Foundation or NSF-WQI (Hanny et al., 2017; Ministry of Environment and Forestry, 2019). NSF-WQI determines five WQI classifications in five ranges of score values, namely very good, good, moderate, bad and very bad criteria, while the IKA-INA method consists of 6 criteria like this method which uses 10 parameter weights (Ratnaningsih et al., 2016, 2018). Each selected parameter has its own weight as shown in table 3 with a total of 1.00.

Table 3. IKA-INA Method Parameter Weights

No.	Parameter	Weight
1	DO	0.143
2	Fecal Coli	0.134
3	COD	0.120
4	pH	0.117
5	BOD	0.113
6	NH3-N	0.092

No.	Parameter	Weight
7	TP	0.085
8	TSS	0.074
9	NO3-N	0.069
10	TDS	0.053
	Total	**1,000**

Source: Ratnanngsih, 2020

The concentration of the parameters resulting from the sampling is then transformed into a sub-index form that has a scale from zero (0) to 100. This can be done by using a sub-index curve or by entering it into the mathematical equation of the sub-index curve (Table 4).

Table 4. Sub-index equations in the IKA-INA method

Parameter	Persamaan Kurva Sub-Indeks IKA-INA	Peruntukan
DO	$y = -0,6574x^2 + 10,157x + 7E-15$	DO≤2
	$y = -0,023x^3 - 0,9933x^2 + 26,124x - 30,173$	DO≤7
	$y = -1,9524x + 109,67$	DO≤8
	$y = -5,8985x + 141,24$	DO≤8,5
	$y = 8,0809x^3 - 227,43x^2 + 2101,2x - 6300,1$	DO≤11
Fecal coli	$y = -1,24x + 100$	FC≤10
	$y = -0,1715x + 89,315$	FC≤100
	$y = 3E-06x^2 - 0,0269x + 74,829$	FC≤1000
	$y = -0,0056x + 56,477$	FC≤5000
	$y = -0,0024x + 40,467$	FC≤10000
	$y = -0,0002x + 18,974$	FC≤50000
	$y = -0,0001x + 14,04$	FC≤100000
	$y = -1E-06x + 3,3727$	FC≤1000000
COD	$y = 0,0204x^2 - 1,4479x + 99,614$	COD≤20
	$y = -2,9803x + 138,43$	COD≤25
	$y = -0,9054x + 86,555$	COD≤50
	$y = -0,0055x^2 + 0,2907x + 40,428$	COD≤100
	$y = 0,0088x^2 - 2,4487x + 171,57$	COD≤150
pH	$Y=0$	pH≤1
	$y = 0,1035x^4 - 0,4796x^3 + 1,5586x^2 + 2,2036x - 2,5054$	pH≤5
	$y = -0,3809x^5 + 14,769x^4 - 225,01x^3 + 1673,7x^2 - 6045x + 8520,9$	pH≤10
	$y = 7,6265x^2 - 181,88x + 1087,8$	pH≤12
BOD	$y = 0,4458x^3 - 3,4443x^2 - 1,3145x + 99,149$	BOD≤5
	$y = -0,0837x^2 - 1,892x + 73,741$	BOD≤15
	$y = 0,0014x^3 - 0,1575x^2 + 3,7312x + 1,3847$	BOD≤30
	$y = 0,007x^2 - 0,9338x + 30,177$	BOD≤50
	$y = 5E-05x^2 - 0,0065x + 1,2$	BOD≤70
NH_3	$y=18703x^6-36932x^5+27566x^4-9960.8x^3+1744.5x^2-187.12x+100$	NH3≤0.7
	$y= 644.68x^3-1507.1x^2+1092.2x-228.14$	NH3≤1
TP	$y = -0,1347x^5 + 2,483x^4 - 16,702x^3 + 50,051x^2 - 73,42x + 100$	TP≤5
	$y = -16,328x + 109,15$	TP≤6
	$y = -0,4975x + 14,165$	TP≤7
	$y = -0,8459x^3 + 23,107x^2 - 209,8x + 637,15$	TP≤10
TSS	$y = 0,0001x^2 - 0,2667x + 96,159$	TSS≤100
	$y = -0,0399x + 74,971$	TSS≤150
	$y = -0,1673x + 94,086$	TSS≤200
	$y = -0,1518x + 90,971$	TSS≤250
	$y = -0,1135x + 81,407$	TSS≤300
	$y = 9E-05x^2 - 0,2127x + 103,2$	TSS≤400
	$y = -0,2694x + 140,03$	TSS≤450
	$y = -0,1921x + 105,23$	TSS≤500
NO_3	$y = -0,0046x^3 + 0,2002x^2 - 4,0745x + 97,77$	NO3≤30
	$y = 1E-06x^4 + 2E-05x^3 - 0,0168x^2 + 0,3103x + 36,034$	NO3≤70
	$y = 0,0039x^2 - 0,8417x + 47,227$	NO3≤100
TDS	$y = -6E-06x^2 - 0,0136x + 96,357$	TDS≤1000
	$y = -4E-06x^2 - 0,0183x + 98,991$	TDS≤2000
	$y = -8E-06x^2 + 0,0252x + 17,624$	TDS≤3500

Source: Ratnanngsih, 2020

The value of the water quality index (IKA) at one point and the monitoring period is the total sum of the multiplication of each parameter sub-index value multiplied by the parameter weight as in the following equation:

$$IKA - INA = \sum_{i=1}^{n} W_i I_i \ldots\ldots (1)$$

In this case:
IKA- INA: Water Quality Index Score
W = The Weight Score
I = The Sub-Index Value

The results of the IKA-INA calculations are then classified into 6 group criteria as shown in table 5.

Table 5. IKA-INA Classification Criteria

SCORE	CRITERIA
100 ≤ I > 90	Very good
90 ≤ I ≥ 80	Good
80 <I ≥ 70	Pretty good
70 <I ≥ 51	Currently
51 <I ≥ 36	Marginal
36 <I ≥ 0	Bad

Source: Ratnanngsih, 2018

Determination of Water Quality Status

Water quality status is calculated usingPollution Index (PI), is a method developed by Sumitomo and Nemerowused to determine the degree of contamination relative to permissible water quality parameters (Ministry of Environment, 2003). Data analysis of insitu measurement results and results of laboratory analysis of water quality parameters obtained are then calculated to determine the status of water quality

This study used the same parameters as the method for determining IKA-INA to assess the water quality status of water resources at 3 monitoring stations, namely site 1, site 2 and site 3.The assessment is based on the level of pollution relative to the permissible water quality parameters, in this case based on the water class written in Government Regulation No. 22 of 2021. The pollutant index value is then determined based on the resultant maximum value and the average value of the concentration ratio per parameter to the quality standard value, as shown on the following formula:

$$PI_j = \sqrt{\frac{\left(C_i/L_{ij}\right)_M^2 + \left(C_i/L_{ij}\right)_R^2}{2}} \ldots\ldots\ldots\ldots (2)$$

In this case:

Lij	:	Concentration of water quality parameters in the quality standard for water use j
ci	:	Concentration of water quality parameters i
PIj	:	Pollution Index for designation j

(Ci/Lij)M : Maximum Ci/Lij Value
(Ci/Lij)R : Average Ci/Lij Value

The IP calculation results are then classified into 4 criteria as in table 6.

Table 6. Pollution Index Classification Method

score	Criteria
0.0 ≤ PI ≤1.0	Good Water Quality
1.0 ≤ PI ≤5.0	Moderately Polluted
5.0 ≤ PI ≤10.0	Polluted
PI > 10.0	Extremely Polluted

RESULT AND DISCUSSION

Cikapundung River Water Quality

The water quality index can be evaluated based on various physical, chemical and bacteriological parameters.Index is a method for assessing the condition of a body of water based on parameters using certain methods in accordance with applicable laws and regulations.Many water quality indices have been formulated around the world that can easily assess the overall water quality in a particular area quickly and efficiently.Water quality began to be categorized in 1965 by Horton, then followed in 1970 by Brown et al. develop a general water quality index that is very strict in selecting parameters and assigning the required weights (Poonam et al., 2013). This effort is supported by the National Sanitation Foundation (NSF), which is then also called NSF-WQI. Rating and weighting curves were developed by seeking advice from experts (Poonam et al., 2013).

TSS and TDS

In this study, the physical parameters measured were TSS (Total Suspended Solid) and TDS (Total Dissolved Solid). Data from measurements of TSS and TDS parameters with quality standards show that the average TSS value is above the quality standard, except at site 2 during sampling in November, the value is much lower than the specified quality standard. TDS is at a safe limit which indicates the value does not exceed the set quality standard value. This applies to all sampling locations, both in March and November. For the TDS parameter, field measurements show values in the range of 98 to 182 mg/l, much lower than the quality standard set at 1000 mg/l.

Table 7. Water Quality of Cikapundung River

No.	Parameter	UNIT	raw Quality	March sample			September sample		
				Site 1	site 2	site 3	Site 1	site 2	site 3
1	DO	mg/L	4	3,43	3.07	3,36	3,47	3,16	2.82
2	FC	Qty/100 mL	1000	540	170	170	220	280	110
3	COD	mg/L	25	69,86	24,27	13.73	31.81	45,54	32,26

No.	Parameter	UNIT	raw Quality	March sample			September sample		
				Site 1	site 2	site 3	Site 1	site 2	site 3
4	pH	-	6.0 – 9.0	7.86	7,6	7.58	7,38	7.88	7,9
5	BOD_5	mg/L	3	24,21	7,52	4,26	9,22	15.78	10
6	NH3-N	mg/L	0.2	0.82	0.17	0.19	0.18	0.16	0.05
7	TP	mg/L	0.2	0.06	0.0096	0.13	0.0096	0.15	0.0096
8	TSS	mg/L	50	379	269	68	14	82	113
9	NO3-N	mg/L	10	5,62	0.76	5.85	1.74	5,8	1.73
10	TDS	mg/L	1,000	98.00	104.00	134	182.00	124	142.00

DO, pH, BOD and COD

Dissolved Oxygen is an important parameter for life for aquatic plants and animals. DO comes from the atmosphere and aquatic plants during photosynthesis. Ontesting the chemical parameters of water quality, the DO produced was in a range of values between 2.82 to 3.47 mg/l. With a quality standard of 4 mg/l, the test results show that the dissolved oxygen level exceeds the set quality standard, it has entered the third class quality standard (Government Regulation, 2021). Testing the pH of river water can show whether the river water is acidic, alkaline or neutral. In this test, the highest value was 7.90 and the lowest was 7.58 so that the pH value was at a safe limit, which indicated that the value did not exceed the set quality standard. The results of the Biological Oxygen Demand test produced a range of values (4.26-24.21) mg/l. With a class 2 quality standard value of 3 mg/l, the value of the test results shows that it has exceeded the set limit. Chemical Oxygen Demand (COD) describes the total amount of oxygen needed to chemically oxidize organic matter, both biodegradable and non-biodegradable or difficult to biologically oxidize into CO2 and H2O.

NH3-N, NO3-N and TP

Water fertility is one of the factors that influence the quality of a body of water. The nutrients that affect the fertility of these water bodies are ammonia, nitrate and phosphate (Effendi, 2003). According to class 2 quality standards, the allowed concentration of nitrate is 10 mg/l, the test results obtain a value range (0.76-5.85) mg/l which indicates the nitrate level still meets the established quality standards.Small amounts of nitrate are necessary for plants and algae to grow in water. Too much nitrate in water, combined with too much phosphate, can cause an algae bloom.

The concentration of ammonia (NH3-N) from the test results generally still meets the quality standards except for the dry season at site1 a concentration of 0.82 mg/l is produced, this indicates the possibility of entry of easily decomposed organic matter both containing nitrogen and non-nitrogen (Effendi, 2003).

Phosphate or phosphate is a chemical parameter thatnaturally have hope in surface water even though the value is very small. Tiny green plants called algae use up phosphates and reproduce rapidly. This is called "algae bloom," which means that the water is covered with algae. This causes a reduction in sunlight entering the water body. Phosphate test results for all sites showed results that met the specified quality standard requirements.

Fecal Coliform

Total Coliform is a group of bacteria used as an indicator of contamination from feces. Its presence in food or drink indicates the possibility of the presence of microbes that are harmful to health. Total Coliform is divided into 2 groups, namely Fecal Coli which comes from human feces and non-fecal Coliform which comes from decomposing animals and plants (Effendi, 2003). The results of Fecal Coli analysis showed that at all sites the value did not exceed the quality standard set in the range (110-540) hml/100 ml from the quality standard 1000 hml/100 ml.

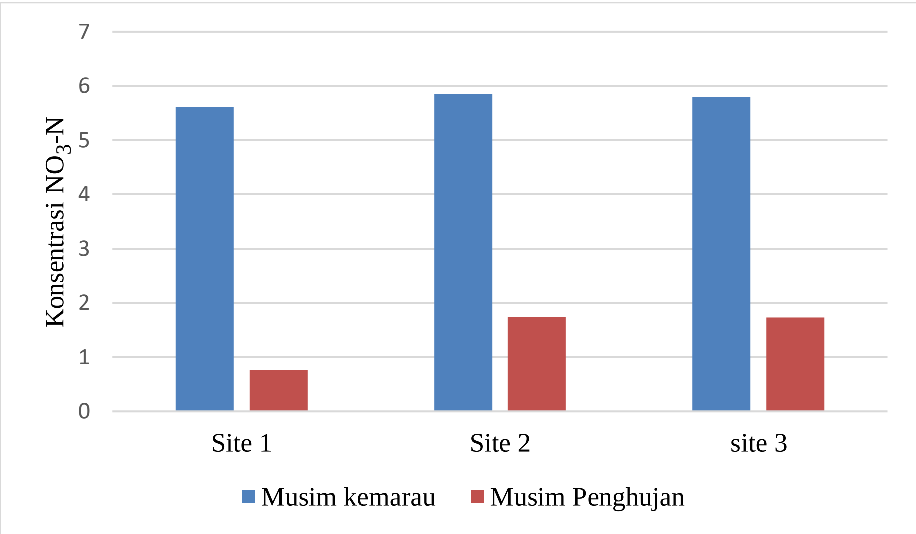

Figure 3. NO_3-N on Cikapunding River

IKA-INA

The IKA-INA method is a modified method of the NSF-WQI used by the US National Foundation (Ratnaningsih et al., 2020). The NSF-WQI is widely used as a reference in the procedure for compiling a water quality index in various countries, and has been widely used for assessing water quality in various countries, including Indonesia.

Table 8. IKA - INA Calculations Representing the Dry Season Sample

NO.	Parameter	Weighting Factor	Site 1		site 2		site 3	
			Sub-Index Values	Sub-Total	Sub-Index Values	Sub-Total	Sub-Index Values	Sub-Total
1	DO	0.143	46,82	6,69	45,52	6,51	41.73	5.97
2	FC	0.134	61,18	8,20	70,34	9,43	67,53	9.05
3	COD	0.12	0.00	0.00	83.58	10.03	0.00	0.00
4	pH	0.117	87.98	10,29	92,91	10.87	87.58	10.25
5	BOD	0.113	0.00	0.00	0.00	0.00	0.00	0.00
6	NH3-N	0.092	0.00	0.00	85.97	7,91	88.15	8,11
7	TP	0.085	95.77	8,14	91.21	7.75	90.06	7.65
8	TSS	0.074	98.00	7,25	94,43	6.99	94.58	7.00
9	NO3-N	0.069	80.33	5.54	79,86	5,51	79,93	5,52
10	TDS	0.053	94.97	5.03	94,43	5.00	94.58	5.01
			Amount	51,16		70.00		58,56

Table 9. IKA – INA calculations representing the rainy season sample

			Site 1		site 2		site 3	
NO.	**Parameter**	**Weighting Factor**	**Sub-Index Values**	**Sub-Total**	**Sub-Index Values**	**Sub-Total**	**Sub-Index Values**	**Sub-Total**
1	DO	0.14	40.00	5,72	47,56	6,80	35.08	5.02
2	FC	0.13	70,34	9,43	69.06	9,25	71,91	9,64
3	COD	0.12	66.09	7,93	0.00	0.00	0.00	0.00
4	pH	0.12	92.60	10.83	95.45	11,17	87,18	10,20
5	BOD	0.11	0.00	0.00	0.00	0.00	0.00	0.00
6	NH3-N	0.09	87,49	8.05	86,77	7.98	93,92	8,64
7	TP	0.09	99.30	8,44	99.30	8,44	99.30	8,44
8	TSS	0.07	0.00	0.00	92.45	6,84	0.00	0.00
9	NO3-N	0.07	94.75	6,54	91,22	6,29	92,26	6,37
10	TDS	0.05	94.88	5.03	93.68	4.97	94.31	5.00
			Amount	61.97		61.75		53.30

The calculation resultsfrom site 1 to site 3 in Marchgenerate valueIKA which fall into the category of "fairly good" and "moderate" (Table 8). For the rainy season, all sites fall into the "medium" category. According to data from the 2021 Ministry of Environment and Forestry in the Indonesian Central Bureau of Statistics, for West Java, the water quality index ranges from 55.25 – 38.73. Value of 55.25 obtained in 2015 and 38.73 obtained in 2018 (Indonesian Environmental Statistics, 2022).

Table 10. IKA-INA of Cikapundung River

March 2022		
site	IKA-INA	Classification
1	51,16	Currently
2	70.00	Pretty good
3	58,56	Currently
Sep-22		
site	IKA-INA	Classification
1	61.97	Currently
2	61.75	Currently
3	53,3	Currently

Pollution Index (PI)

Analysis of data from field measurements and results of laboratory analysis of water quality parameters obtained is then calculated to determine the status of water quality using the Pollution Index (PI) method based on the Decree of the Minister of Environment of the Republic of Indonesia Number 115/2003. The results of the calculations show that the pollution index values produce values in the range of 1.36 to 4.18 (Table 11). This means that the Cikapundung River is polluted in the category "Moderately Polluted".The resulting value is the value at the time and point of sampling. Value can change depending on domestic and industrial activities along its path.

Table 11. Pollution Index of Cikapundung River

March 2022		
site	Pollution Index (PI)	Classification
1	4,18	Moderately Polluted
2	1.36	Moderately Polluted
3	3.38	Moderately Polluted
Sep-22		
site	Pollution Index (PI)	Classification
1	3.38	Moderately Polluted
2	2,5	Moderately Polluted
3	2.66	Moderately Polluted

CONCLUSION

The conclusions that can be drawn from this research are; (1) the results of water sample testing taken at the sampling points at each site show that the dominant parameters that do not meet the stipulated water quality standards are TSS, DO, BOD and COD. The high parameters are caused by contamination of river water by domestic waste generated from residential areas with poor sanitation infrastructure. The condition of land use in all sites where the right and left are dominated by settlements affects the quality of river water, especially rice fields and settlements, (2) from the results of calculations based on the modified Water Quality Index-National Sanitation's Foundation (IKA-INA) method, the water quality of the Cikapundung River from site 1 to site 3 in March with an IKA value of 51.15-70.00, as well as for November of the same year, the status is moderate at site 1 to site 3 with an IKA-INA score between 53.30-61.97, and (3) the pollution index produces a value of “Moderately Polluted” for all sites both during the dry and rainy seasons with IP values ranging from 1.36 to 4.38

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