Determination of Quality Status of Seketak River in Indonesia using CCME - WQI and Pollution Load

ALDHIMAS BAGUS ZEVRIAWAN[1], CHURUN A'IN[2], SITI RUDIYANTI, SURYANTI[3]
[1, 2, 3]*Department of Aquatic Resource, Faculty of Fisheries and Marine Science, Diponegoro University, Semarang, Indonesia*

Abstract- Rapid development in the era of industry 4.0 and society 5.0 has a huge impact on the environment, including aquatic ecosystems. Seketak river, one of the rivers flowing in Semarang City, has become one of the rivers with poor water quality due to various human activities such as domestic, industrial, and livestock. This research aims to determine the water quality status and pollution load of Seketak River using the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) method and calculate the maximum capacity of pollution load based on physical and chemical parameters. Sampling was conducted at four stations in October 2024, including variables such as Total Suspended Solid (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrite, total phosphate, lead, and iron. The results showed that the water quality status of Seketak river was in the "poor" category at all stations with the lowest value recorded at Station 2 due to the dominance of domestic waste from settlements, student boarding houses, and shops. The pollution load of COD, BOD, iron, nitrite, and lead exceeded the maximum capacity, with the largest contribution from Station 3. This indicates a lack of waste management, including wastewater treatment plants (WWTP) at the household scale. This study underscores the importance of effective waste management to reduce the impact of pollution and improve the water quality of Seketak River.

Indexed Terms- water quality status, Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), Pollution Load, Seketak River, poor.

I. INTRODUCTION

The massive development in the era of industry 4.0 and society 5.0 is not only good for Indonesia. Semarang City, Tembalang Village is one example, this area is an area that has experienced a surge in population increase since 2017, this surge is caused by the emergence of well-known universities in the area. The increase in population has led to a high level of human activity, which of course has an impact on the land and water environment. For example, Seketak River is one of the rivers that flows from Banyumanik Subdistrict and empties into Tembalang Subdistrict, precisely at the Diponegoro University Education Reservoir. Diponegoro University Education Reservoir was built for the purpose of maintaining the stability of the local ecosystem, preventing flooding, increasing water absorption capacity, and supporting various business activities. In addition, the reservoir is also utilized as a recreational area, such as a fishing spot, and a source of water for the surrounding community for their daily needs. However, with poor water quality, the community cannot utilize the water in the reservoir optimally. The pollution that occurs in the Seketak watershed is thought to come from natural factors such as the interaction between water and rocks and anthropogenic human activities around the Seketak River. Human activities such as industrial, domestic, and livestock activities are factors that cause a decrease in water quality. The pressure of activities that cause impacts on rivers has the potential to disrupt the quality and sustainability of the ecosystem if not managed properly (Hudiyah and Saptomo, 2019).

This study aims to determine the status of water quality based on physical and chemical parameters, including pH, temperature, Total Suspended Solid

(TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrite (as N), total phosphate, lead (Pb), and iron (Fe). The analysis was conducted by combining 2 methods, namely using CCME - WQI with the aim to determine the status of Seketak River water quality and Pollution Load to determine the maximum capacity that can be accepted by Seketak River. This research is expected to provide an overview of the water quality of Seketak River so that the government and related agencies can provide the right policy to prevent worse pollution in Seketak River.

II. MATERIALS AND METHODS

The research study area is located in the Seketak River Basin, which has a river length of ± 10,571 km located in Banyumanik and Tembalang Subdistricts, Semarang City, Indonesia. Geographically, Seketak River is one of the tributary rivers of Kaligarang River. This river empties into the Diponegoro University Education Reservoir which serves as a clean water reservoir and flood prevention in Semarang City.

2.4 Sampling point and data sources

Sampling was conducted in October 2024 with 4 sampling points based on pollutant sources which can be reviewed in figure 1. Station 1 is adjacent to the upstream of the river as well as a source of iron industry pollutants with coordinates S: 7°4'4.44” and E: 110°24'46.48”, this station illustrates the influence of chemical waste entering the water body. Station 2 is a source of domestic pollutants such as residential areas, student boarding houses, and small shops with coordinates S: 7°3'22.11” and E: 110°26'17.54”, this location was chosen because it has great potential to produce domestic and organic waste that can affect water quality. Station 3 is a source of pollutants from campus activities with coordinates S: 7°5'51.27” and E: 110°43'86.55”, this point was studied to determine the effect of student activities on river water quality. Station 4 is adjacent to the downstream as well as a source of pollutants from chicken, cow and goat farming activities with coordinates S: 7°5'47.05” and E: 110°44'18.81”, this station was chosen to determine the effect of organic waste from chicken, cow, and goat farms on the aquatic ecosystem, as well as to reflect the downstream condition of Seketak river.

2.2 Sample collection

Sampling was conducted in October 2024 with a 2-week interval of 2 repetitions. Sampling using a 5 liter sample bottle. Water sampling was conducted at ½ the depth of the river surface with composite samples from 3 points of each station including ¼, ½, and ¾ the width of the river in one sample bottle. Water samples were stored using 1000ml polyethylene (PE) bottles and put in a coolbox with a temperature of ± 4℃. Measurements of variables such as Temperature, pH, and Dissolved Oxygen (DO) were carried out in situ with pH meter and DO Meter tools.

2.3 Analysis Procedures

The analysis of water samples such as BOD, COD, Total Phosphate Nitrite, Lead, and Iron was submitted to the Semarang City Environmental Agency Laboratory and the TSS variable was tested at the Fish and Environmental Resource Management Laboratory, Faculty of Fisheries and Marine Sciences, Diponegoro University. Testing of TSS variables was carried out using the gravimetric method, BOD variables using the incubation method carried out for 5 days at a temperature of 20 ℃, COD using the spectrophotometric closed reflux method, total phosphate variables using the spectrophotometer method with ascorbic acid reduction, nitrite variable testing using the spectrophotometric method, testing for heavy metals such as lead and iron using the Atomic Absorption spectrometry (SSA) method.

2.4 Data Analysis

2.1 Canadian Council of Ministers of the Environment Water Quality Index

Determination of the water quality status of Seketak River using the CCME-WQI method. The method is used because it has the advantage of being able to integrate various variables, and has high flexibility in parameter selection (Panagopuolos et al. 2024). The CCME-WQI approach involves three main factors, namely F1 (scope), which calculates the proportion of water quality variables that do not meet quality standards; F2 (frequency), which measures the frequency of violations of quality standards by the measured parameters; and F3 (amplitude) indicates the degree or degree of deviation of variable concentrations from the specified quality standards. F1, F2, and F3 are calculated as follows:

F1 (Scope), expresses the percentage of variables that do not meet quality standards, within a certain period of time.

$$F_1 = \frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables} - 1$$

F2 (*Frequency*), expresses the percentage of tests that do not meet quality standards (failed tests)

$$F_2 = \frac{Number\ of\ failed\ test}{Total\ number\ of\ tests} - 1$$

F3 (*Amplitude),* expresses the average relative deviation of the variables that do not meet the quality standard. F3 is calculated using 3 steps;

1) Excursion, expresses the relative difference between a parameter measurement result and a predetermined limit, calculated proportionally to the threshold. Excursion is calculated only for parameters that do not meet the water quality criteria. Here if the test value is more than the quality standard:

$$excursion = \left(\frac{Failed\ test\ value}{Objective}\right) - 1$$

If the test value is less than the quality standard:

$$excursion = \left(\frac{Objective}{Failed\ test\ value}\right) - 1$$

2) Normalized Excursion (nse), expresses the test excursion from the quality standard divided by the total number of tests

$$excursion = \left(\frac{Objective}{Failed\ test\ value}\right) - 1$$

3) Then calculate using the function with the sum scale of nse

$$F_3 = \frac{nse}{0{,}01nse + 0{,}01}$$

CCME-WQI is calculated with the following equation:

$$CCME = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1{,}732}\right)$$

Determination of water quality status based on CCME - WQI can be reviewed in table 1:

Table 1. Determination of Water Quality Status Based on CCME- WQI

CCME-WQI	Status
95-100	Excellent
80-94	Good
65-79	Fair
45-64	Marginal
0-44	Poor

Source: CCME-WQI (2017)

2.4.2 Pollution Load

Pollutant elements such as Total Suspended (TSS), pH, temperature, Dissolved Oxygen (DO), Nitrite (as N), Total Phosphate (as P), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Iron (Fe) and Lead were calculated using the BP equation to determine the amount of pollution load in Seketak River. Calculation of actual pollution load using the equation,

$$\boldsymbol{BP_A = Q\ x\ C_M}$$

Actual pollution load is used to calculate the amount of pollution load based on each variable pollutant element, Q is the measured discharge, C_M is the actual concentration.

The maximum amount of pollution load that can be accommodated by waters can be measured using the maximum pollutant load calculation using the following equation,

$$\boldsymbol{BP_M = Q\ x\ C_{BM}}$$

The maximum pollution load serves to determine whether the actual pollution load value has exceeded the maximum pollution load or not. If the actual pollution load exceeds the maximum pollution load, it is said that the river has been polluted, because it exceeds the acceptable capacity. The C_{BM} variable is a variable quality standard used with reference to Government Regulation of the Republic of Indonesia Number. 22 of 2021 concerning the Implementation of Environmental Protection and Management Class II.

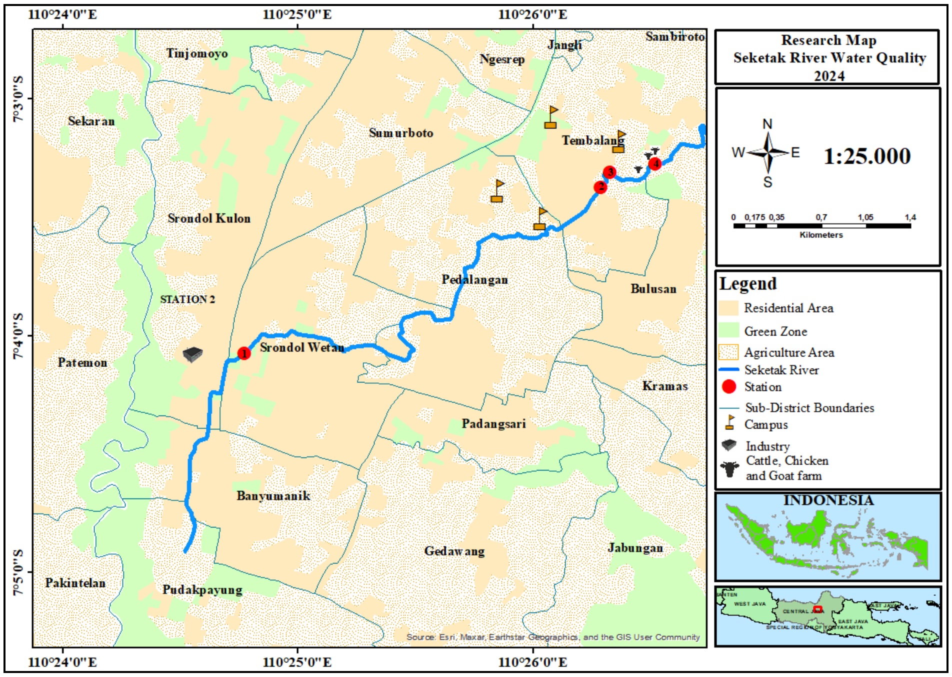


Figure 1. Map of Sample Point

III. RESULT

3.1 Water Quality of Seketak River

The results of the analysis of the physical and chemical parameters of Seketak River water during the 2 repetitions can be reviewed in tables 2 and 3. During the 2 repetitions, the temperature of Seketak River water was between 29.2°C to 33.2°C. The highest temperature was recorded at station 3 (repetition I) and station 2 (repetition I and II), and the lowest temperature at station 1 (repetition II). The TSS value in Seketak River was recorded at 5.1 mg/L to 21.74 mg/L. The highest TSS was recorded at station 2 (repetition II) and the lowest at station 1 (repetition II).

The Dissolved Oxygen (DO) concentration in Seketak River during the two repetitions was recorded to be between 4.0 ppm and 6.5 ppm. The highest DO values were recorded at station 1 (repetition II) and station 4 (repetition I), while the lowest values were recorded at station 2 (repetition I) and station 3 (repetition II). Nitrite concentration in Seketak River was recorded at 0.21 mg/L to 0.66 mg/L. The highest nitrite value was recorded at station 1 (repetition II) and the lowest at station 4 (repetition I). The pH value in Seketak River was recorded between 7.5 and 9.3. The highest pH was recorded at station 3 (repetition II) and the lowest pH was recorded at station 4 (repetition I). BOD values were recorded at 15 mg/L to 22 mg/L. The highest BOD values were recorded at stations 3 and 4 (repetition II), while the lowest value was recorded at station 1 (repetition I). COD in Seketak River was recorded between 33 mg/L to 48 mg/L. The highest COD values were recorded at stations 3 and 4 (repetition II), while the lowest values were recorded at stations 1 and 2 (repetition I). Total Phosphate concentration was recorded at 0.01 mg/L to 0.13 mg/L. The highest Total Phosphate value was recorded at station 1 (repetition II) and the lowest at station 3 (repetition II). Iron (Fe) concentration was recorded at 0.18 mg/L to 1.07 mg/L. The highest Fe value was recorded at station 3 (repetition I) and the lowest at station 1 (repetition II). Lead (Pb) concentration was recorded at 0.01 mg/L to 0.05 mg/L. Pb values were highest at stations 2 and 4 (repetition II), while the lowest values were at stations 1 and 3 (repetition I).

Table 2. Water Quality Testing Result Repetition I

Variable	Station				Average	Quality Standard	Unit
	1	2	3	4			
Physical Parameters							
Depth	0,6	0,8	0,75	0,2	0,59	#	m
Brightness	0,38	0,75	0,55	-	0,56	#	m
Debit	0,40	1,16	2,26	0,39	1,05	#	m/s^2
Total Suspended Solid (TSS)	5,34	13,78	11,08	5,5	8,93	50	mg/l
Temperature	29,9	32,2*	33,2*	31,4*	31,68*	Deviation 3	°C
Chemical Parameters							
Potential of Hydrogen (pH)	7,7	7,8	8	7,5	7,75	6-9	-
Dissolved Oxygen (DO)	6,1	4	6,1	5,8	5,50	4	ppm
Nitrit	0,21*	0,22*	0,22*	0,47*	0,28*	0,06	mg/L
Total Phosphate	0,01	0,01	0,01	0,01	0,01	0,2	mg/L
BOD	15*	16*	20*	21*	18,00*	3	mg/L
COD	33*	33*	43*	44*	38,25*	25	mg/L
Iron (Fe)	0,32*	0,78*	1,07*	0,67*	0,71*	0,3	mg/L
Lead (Pb)	0,01	0,01	0,01	0,02	0,01	0,03	mg/L

Table 3. Water Quality Testing Result Repetition II

Variable	Station				Average	Quality Standard	Unit
	1	2	3	4			
Physical Parameters							
Depth	0,56	0,72	0,75	0,2	0,56	#	m
Brightness	0,35	0,59	0,66	-	0,53	#	m
Debit	0,46	0,99	2,92	0,61	1,24	#	m/s^2
Total Suspended Solid (TSS)	5,1	21,74	18,78	6,06	12,92	50	mg/l
Temperature	29,2	31,1*	31,2*	30,6*	30,53*	Deviation 3	°C
Chemical Parameters							
Potential of Hydrogen (pH)	8,9	8,5	9,3*	9,2*	8,98	6-9	-
Dissolved Oxygen (DO)	6,5	4,7	4,7	6,4	5,58	4	ppm
Nitrit	0,66*	0,48*	0,44*	0,39*	0,49*	0,06	mg/L
Total Phosphate	0,13	0,06	0,07	0,09	0,09	0,2	mg/L
BOD	20*	19*	22*	21*	20,50*	3	mg/L
COD	45*	41*	48*	44*	44,50*	25	mg/L
Iron (Fe)	0,18*	0,53*	0,44*	0,49*	0,41*	0,3	mg/L
Lead (Pb)	0,03*	0,05*	0,03*	0,05*	0,04*	0,03	mg/L

3.1.2 Analysis of Water Quality Status Based on CCME-WQI

The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) method is used for the assessment of water quality based on three main aspects, namely f1 (Scope) which serves to measure the proportion of variables that exceed the safe limit, f2 (Frequency) which is how often the variable exceeds the threshold, and f3 (Amplitude) which measures how far the variable exceeds the limit. The CCME method can be widely used and reflects water quality conditions for various purposes (Wu et al. 2017; Gao et al. 2016). Analysis of the water quality status of the Seketak River measured using the CCME-WQI (Canadian Council of Ministers of the Environment Water Quality

Index) method obtained results regarding the water quality status which can be reviewed in figure 2. The water quality of the Seketak River is in the poor category at all stations as shown in Figure 4.11, with a value at station 1 of 43.552, station 2 of 36.579, station 3 of 40.968, and at station 4 of 36.721. Referring to the CCME WQI scoring, it can be concluded that the water quality status of stations 1 - 4 of the Seketak River is poor.

3.1.3 Pollution Load Analysis of Seketak River

The results of the Seketak River Pollution Load analysis for 2 repetitions can be reviewed in tables 4 and 5. Based on repetitions I and II, the average and maximum actual pollution load data of TSS, nitrite, total phosphate, BOD, COD, iron, and lead variables were obtained. The highest average actual pollution load was at station 3 with TSS variables of 3451.084 kg/day; nitrite of 76.958 kg/day; total phosphate of 3.056 kg/day; BOD of 4729.160 kg/day; COD of 10255.952 kg/day; iron of 160.088 kg/day; lead of 4.760 kg/day. The lowest average actual pollution load was recorded at station 1 with TSS variables of 520.951 kg/day; nitrite of 16.633 kg/day; total phosphate of 2.741 kg/day; BOD of 651.452 kg/day; COD of 1452.963 kg/day; iron of 9.021 kg/day; lead of 0.764 kg/day.

Table 4. Actual Pollution Load of Seketak River

Station	Repetition	Actual Pollution Load (kg/day)						
		TSS	Nitrit	Total Phospate	BOD	COD	Iron	Lead
1	I	182,311	7,170	0,341	512,111	1126,644	10,925	0,341
	II	859,591	26,096	5,140	790,792	1779,283	7,117	1,186
	Average	520,951	16,633	2,741	651,452	1452,963	9,021	0,764
2	I	1383,481	22,088	1,004	1606,364	3313,126	78,310	1,004
	II	1850,655	40,861	5,108	1617,408	3490,196	45,117	4,256
	Average	1617,068	31,474	3,056	1611,886	3401,661	61,714	2,630
3	I	2166,548	43,018	1,955	3910,737	8408,084	209,224	1,955
	II	4735,619	110,952	17,651	5547,584	12103,819	110,952	7,565
	Average	3451,084	76,985	9,803	4729,160	10255,952	160,088	4,760
4	I	185,514	15,853	0,337	708,324	1484,108	22,599	0,675
	II	319,558	20,566	4,746	1107,380	2320,225	25,839	2,637
	Average	252,536	18,209	2,542	907,852	1902,167	24,219	1,656

Table 5. Maximum Pollution Load of Seketak River

Station	Repetition	Maximum Pollution Load (kg/day)						
		TSS	Nitrit	Total Phospate	BOD	COD	Iron	Lead
1	I	1707,036	2,048	6,828	102,422	853,518	10,242	1,024
	II	1976,981	2,372	7,908	118,619	988,490	11,862	1,186
	Average	1842,009	2,210	7,368	110,521	921,004	11,052	1,105
2	I	5019,888	6,024	20,080	301,193	2509,944	30,119	3,012
	II	4256,337	5,108	17,025	255,380	2128,168	25,538	2,554
	Average	4638,113	5,566	18,553	278,287	2319,056	27,829	2,783
3	I	9776,842	11,732	39,107	586,611	4888,421	58,661	5,866

	II	12608,145	15,130	50,433	756,489	6304,072	75,649	7,565
	Average	11192,494	13,431	44,770	671,550	5596,247	67,155	6,716
4	I	1686,486	2,024	6,746	101,189	843,243	10,119	1,012
	II	2636,620	3,164	10,546	158,197	1318,310	15,820	1,582
	Average	2161,553	2,594	8,646	129,693	1080,777	12,970	1,297

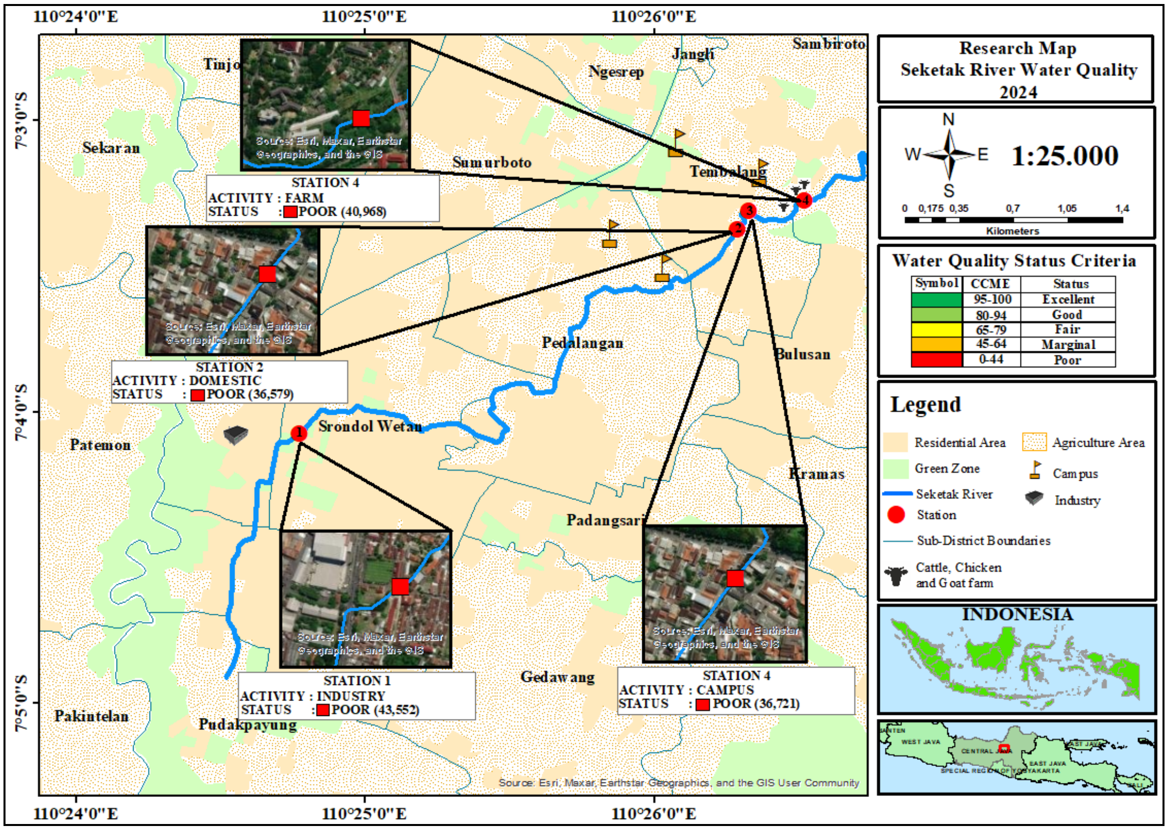


Figure 2. Seketak River Water Quality

3.2 Discussion

Based on the research results obtained, the Seketak River discharge value ranges from 0.39-2.92 m3/s. The rate of water discharge can be influenced by several factors such as river morphology (river slope, river shape, depth, river width) and meteorology (weather and rainfall). The river rate is influenced by the river network (river tiller) (Utama et al., 2018). The slow discharge value at Seketak River is thought to be due to weather conditions when sampling was not raining. The discharge value at station 3 is quite different from the other stations, this difference is caused by the shape of the flow at station 3 which is more downhill. There are other factors that cause station 3 to have a heavier discharge, namely the presence of a settlement before station 3 where domestic waste directly enters the river waters. River topography and geomorphology, land cover and vegetation cover affect the rate of river discharge (Neno et al., 2016). Decomposition of organic matter is faster in rivers that have a heavy discharge. Slow discharge in waters has the potential to increase the viscosity of organic matter (Mutmainah et al., 2022; Mandaric et al., 2018).

The obtained temperature of Seketak River ranges from 29.2℃ - 33.2℃ which can be reviewed in figure 3. The temperature obtained exceeds the quality standards of class I to IV where the temperature exceeds 3℃ of the actual average water temperature. Light intensity is the main factor of high water temperature in Seketak River. High water temperature can be influenced by the intensity of sunlight (Rani and Afdal, 2021). High temperature is also influenced by the stirring process. (Bahri et al, 2022). Water quality can be influenced by water temperature, because water temperature is one of the limiting factors in the photosynthesis process of phytoplankton to produce oxygen. There is a linear relationship between sunlight intensity and the photosynthesis process (Zainuri et al., 2023). High temperatures affect the survival of aquatic biota. This happens because temperature will affect changes in dissolved oxygen which causes an influence on the opening of the fish operculum in the respiration process (Nasution et al., 2023). However, it is precisely with high temperatures that the decomposition process of organic substances originating from agriculture, industry, and urban areas can be faster (Elassassi et al., 2022; Nemati et al., 2016).

Total Suspended Solid content recorded from all stations ranged from 5.1 - 21.74 mg/L which can be reviewed in figure 3. Based on Government Regulation Number 22 of 2021 Class II shows that the TSS levels obtained are still below the specified quality standard of 50 mg/l. The highest TSS content of Seketak River is at station 2, which is a source of pollutants from community settlements, student boarding houses, and shops. The high TSS at this station proves the influence of human activities on the pollution of waters, this is because waste has the potential to directly enter water bodies (Winarsih et al. 2016). The high concentration of TSS is influenced by the amount of waste entering the waters, and the high TSS will affect the concentration of TDS in the waters (Sari, 2015). Discharge is also one of the factors that cause high TSS, because high discharge can carry sediment particles downstream (Zulfikar and Kusratmoko, 2017). Particles that enter water bodies can cause sedimentation or siltation. High TSS concentrations also affect the brightness of the water, reducing the ability of light to penetrate the water. This is in accordance with the results of the study, which showed that the brightness of the water decreased as the TSS concentration increased. Indirectly, TSS impacts water quality by inhibiting the photosynthesis process of phytoplankton due to the disruption of sunlight penetration into the water body (Wisha et al., 2019). The turbidity level of a water body is also influenced by the TSS concentration where both have a positive relationship. The higher the TSS concentration, the higher the turbidity level. This high turbidity can reduce the productivity of aquatic biota and potentially disrupt the balance of aquatic ecosystems (Sinaga et al., 2024).

The pH or acidity obtained from 4 stations ranges from 7.5 - 9.3 which can be reviewed in figure 3. This shows that there is a pH that exceeds the specified quality standard of 6-9. The high pH that exceeds the quality standard in Seketak River does not have a major influence on water quality, because it is still in the normal pH quality range for freshwater. The process of photosynthesis, decomposition of organic matter and the activity of aquatic biota is one of the factors that affect the pH concentration. The pH concentration will change during the day, this is because there is a process of photosynthesis in phytoplankton. Phytoplankton will absorb CO_2 to carry out photosynthesis, so that CO_2 levels will decrease and increase pH in waters (Pramleonita et al. 2018). However, the respiration process carried out by aquatic biota causes pH to become acidic because it releases carbon dioxide and absorbs existing dissolved oxygen. This also occurs during the process of decomposition of organic matter assisted by the presence of microorganisms, where there will be an increase in the need for dissolved oxygen in the waters and release carbon dioxide, causing the pH to decrease (Supriatna et al. 2020). In addition, organic waste that enters water bodies also affects pH conditions, such as organic waste from agricultural and household activities. The composition of soil or aquatic substrates such as mineral content, organic matter contained in the substrate can be one of the factors causing acidic pH, because it is easily dissolved in waters (Anggraini et al. 2022).

Dissolved Oxygen (DO) obtained from 4 stations ranged from 4 - 7.4 mg/l which can be reviewed in figure 3. This shows that the DO concentration obtained is in a safe condition. Station 2 has the lowest DO concentration. Domestic waste from residential areas, student boarding houses and shops is one of the factors for the low DO concentration at the station. Low DO levels are caused by domestic, urban, industrial and livestock waste entering water bodies (Sugianti and Astuti, 2018). Sunlight intensity is also a factor in the difference in DO content at each station, this occurs at station 2 because there is no canopy cover (vegetation covering). The high intensity of sunlight is in line with the increase in water temperature. Water temperature is inversely proportional to dissolved oxygen content, so high temperatures will cause low DO concentrations (Brennan, 2017). The DO concentration of Seketak River also meets the minimum requirements but is not yet included in the optimum conditions. According to Pakpahan et al. (2023), the DO concentration to support the biochemical oxidation process is between 3-4 mg/l with an optimum condition of 5-7 mg/l.

Nitrite concentrations recorded at all Seketak River stations ranged from 0.21 - 0.66 mg/l as shown in figure 3. Nitrite concentrations from all stations exceeded the quality standard set for class II rivers of 0.06 mg/l. Household waste discharged into the river and activities adjacent to the river are one of the factors for the high nitrite content in the river. However, the main factor that causes the high nitrite content is the livestock farm located at station 4, where chicken, cow and goat farm waste directly enters the water body. This is in accordance with the research of Olivianti et al. (2016), which found high nitrite levels in river bodies adjacent to chicken manure waste disposal pipes. Waters can be toxic due to high nitrite content. High nitrite will easily oxidize $Fe2+$ in hemoglobin biota which affects the rate of oxygen movement in the blood and damages biota body tissues. Nitrite is also toxic to fish larvae (Rejito, 2019).

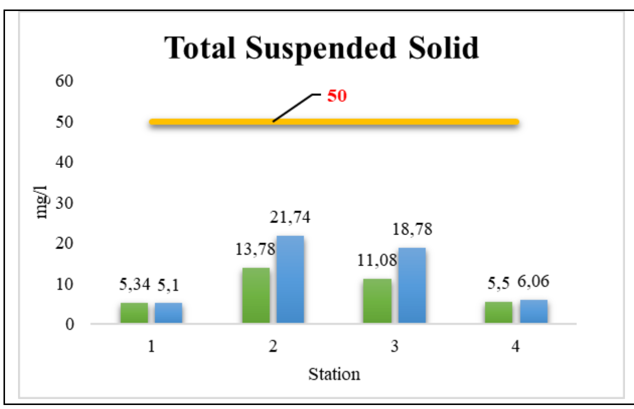
The concentration of total phosphate at stations 1 to 4 was recorded to range from 0.01 - 0.13 mg/l which can be reviewed in figure 3. The concentration obtained is still within the safe range of below 0.2 mg/l. It was noted that stations 1 and 4 had the highest total phosphate concentrations. Community waste and the weathering of rocks that are the substrate of the river are one of the factors for the high concentration of total phosphate at these stations. There are other factors that increase phosphate levels such as livestock activities found at station 4. Livestock, domestic waste such as detergents contribute to the increase in phosphate levels in waters (Ramadhan and Yusanti, 2020). High concentrations of phosphate and nitrate can cause algal blooms (Tungka et al. 2016). High algae growth rates can occur due to phosphate and nitrate because these elements are essential elements for algae growth (Misbach et al. 2021). This causes phosphate to be one of the indicators to determine the level of water fertility.

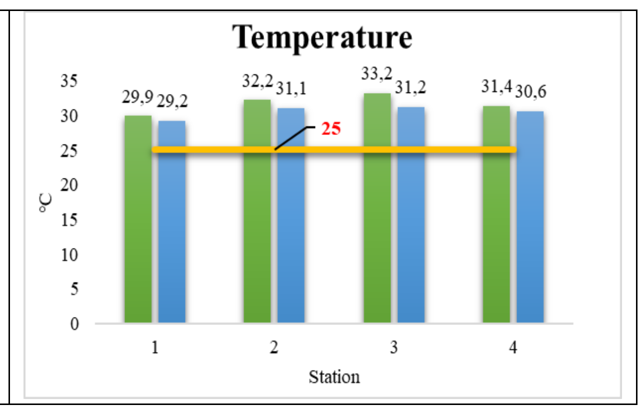
Based on Government Regulation No. 22 of 2021 regarding the designation of class II river water, the BOD concentration of Seketak River has exceeded the established quality standard of a maximum of 3 mg/l. Recorded from 4 stations, the BOD concentration ranged from 15 - 22 mg/l which can be reviewed in figure 3. Station 3 is the point with the highest BOD concentration. High student activity is one of the contributing factors because it causes waste generation around Seketak River. The runoff of domestic waste around station 2 is also suspected to be a factor in the high BOD concentration at station 3. The BOD concentration will be high when there is high organic matter entering the water body and generally occurs during peak hours. This is in line with the research conducted, where sampling was carried out during peak hours and when the water was receding. When rush hour and low tide will cause an increase in organic matter pollution in the waters (Haque et al. 2024). The presence of chicken, cow and goat farms also contributed to the high concentration of BOD in Seketak River. This research is in line with that conducted by Napitupulu et al. (2024), the main contributor to high BOD concentrations comes from cattle, goat, and tofu industries. High BOD levels indicate that there is an increase in the need for dissolved oxygen to decompose organic matter, this threatens the life of aquatic biota because it causes a decrease in DO stocks in the waters.

BOD and COD concentrations have a linear correlation shown by the COD concentrations obtained which ranged from 33 - 48 mg/l which can be reviewed in figure 3. The high concentration obtained shows that it has exceeded the quality standard set at 25 mg/l. A linear correlation is also shown by the high COD concentration at station 3 as well as the highest BOD concentration. The disposal of laundry waste from settlements that are not equipped with a household-scale Wastewater Treatment Plant (WWTP) causes the waste to enter the water body directly until it is carried to station 3. The high concentration of BOD and COD has a direct impact on the concentration of DO in the waters so that it has the potential to cause a decrease in water quality (Pribadi et al., 2016).

Iron concentrations in the Seketak River from station 1 to 4 ranged from 0.18 - 0.67 mg/l, which can be seen in figure 3. The high iron concentrations at some stations indicate that they exceed the specified quality standard of 0.3 mg/l. Domestic waste made from metals such as springbeds, wire, and construction waste are the main causes of high iron concentrations in water. Natural factors such as rocks resulting from volcanic eruptions can be a factor in high iron concentrations in rivers due to the weathering process (Bundschuh et al. 2021). Geographically, the Seketak River is located adjacent to the Kaligarang River, which indicates that the Seketak River is a tributary of the Kaligarang River. According to Setyowati (2008), the Kaligarang River is a river that originates from Mount Ungaran. The mountain once erupted in ancient times and many rocks from the mountain were found in several rivers in Semarang City. High iron content generally comes from industrial waste carried by the current (Ishak et al., 2023). High iron content has a negative impact on fish metabolism because it easily accumulates into body tissues through the food chain.

Lead concentrations obtained from stations 1 to 4 Kali ranged from 0.01 - 0.05 mg/l which can be reviewed in figure 3. The high concentration of lead shows that there are several stations that exceed the quality standard of class II river which is 0.03 mg/l. High lead concentrations were found at stations 2 and 4. Busy and crowded road conditions are a major factor in the high lead content at these stations. Motor vehicle waste such as oil, grease, and gasoline are the main sources of high lead (Alisa et al. 2020). Waters containing heavy metals such as lead easily accumulate in the food chain and are toxic. Lead toxicity can increase if the water has an acidic or low pH, this is because a low pH causes the solubility of lead metal to be higher (Desriyan et al. 2015). The accumulation of lead in water has the potential to cause disorders of the human nervous system, kidneys, and digestive system and easily accumulates in the body of aquatic organisms. Lead accumulation will indirectly damage the overall aquatic ecosystem, reduce species diversity, and affect the aquatic food chain. Fish are at the top of the aquatic food chain and are therefore most vulnerable to lead exposure (Lee et al. 2019). Low concentrations of lead can be fatal to aquatic biota due to bioaccumulation (Kim and Kang, 2015). Lead not only affects the life of biota but also plants that live through sediments (Kumar et al., 2020).





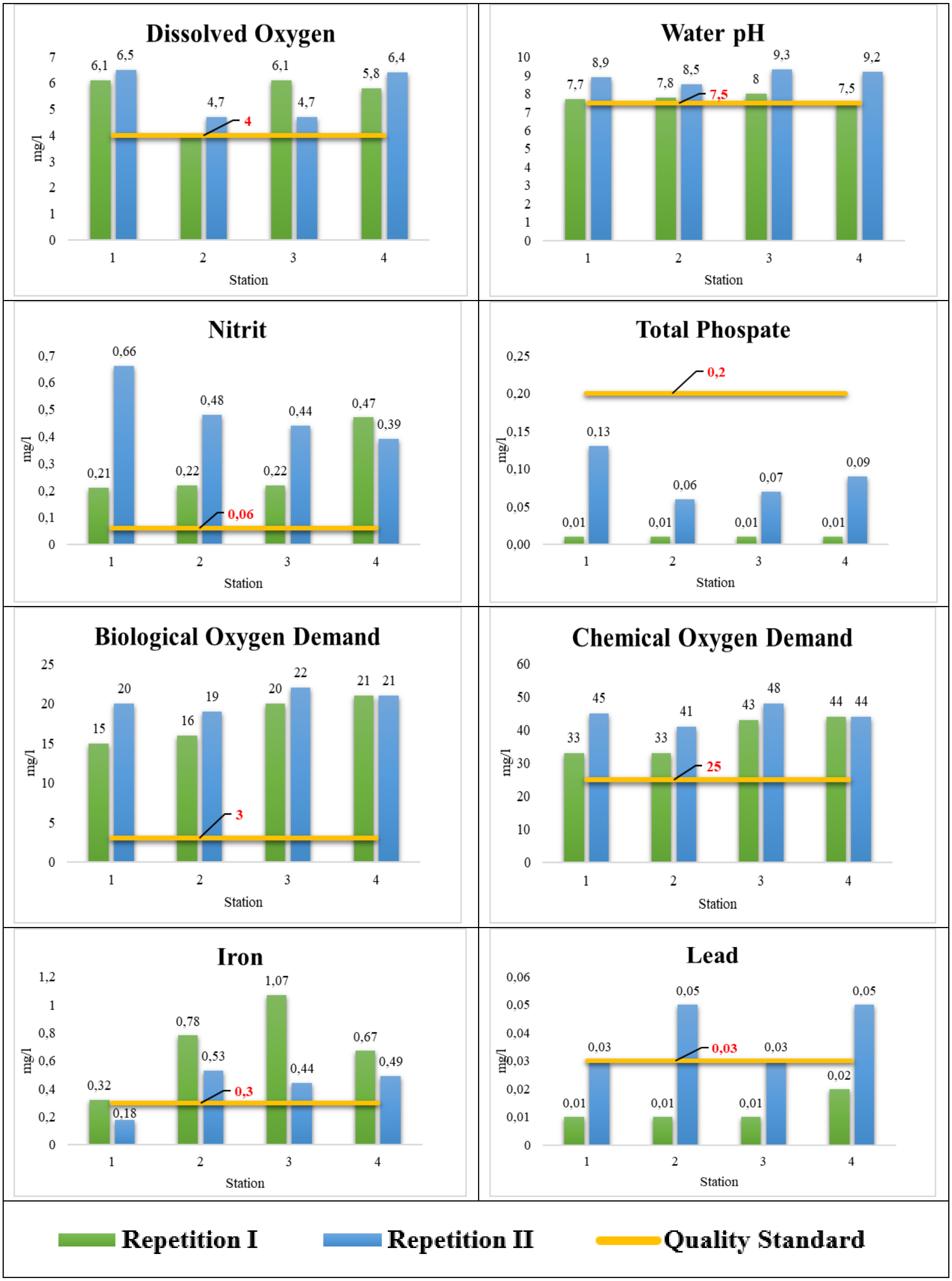

Dissolved Oxygen
mg/l
Station
6,1 6,5 4,7 4 6,1 4,7 5,8 6,4
Water pH
Station
7,7 8,9 7,8 8,5 7,5 8 9,3 7,5 9,2
Nitrit
mg/l
Station
0,21 0,66 0,22 0,48 0,06 0,22 0,44 0,47 0,39
Total Phospate
mg/l
Station
0,2
0,01 0,13 0,01 0,06 0,01 0,07 0,01 0,09
Biological Oxygen Demand
mg/l
Station
15 20 16 19 3 20 22 21 21
Chemical Oxygen Demand
mg/l
Station
33 45 33 41 25 43 48 44 44
Iron
mg/l
Station
0,32 0,18 0,78 0,53 0,3 1,07 0,44 0,67 0,49
Lead
mg/l
Station
0,01 0,03 0,01 0,05 0,03 0,01 0,03 0,02 0,05
Repetition I
Repetition II
Quality Standard

Figure 3. Water Quality Variable Concentration of Seketak River

3.2.1 CCME – WQI of Seketak River

Based on the analysis of the water quality status of Seketak River using the CCME-WQI method as a whole, it shows that it is in poor condition, which can be seen in Figure 4. The variables that have the highest impact on the water quality status of Seketak River are BOD, COD, nitrite, iron, and lead. The worst water quality status was recorded at station 2 with a value of 36.579 which is thought to be the largest contribution of pollutants from domestic waste, thus station 2 is more polluted than stations 1, 3 and 4. High concentrations of BOD and COD are caused by domestic, livestock and industrial waste that produces heavy metal waste and is difficult to decompose. In addition, BOD and COD concentrations have a direct impact on decreasing DO concentrations due to the high need for oxygen to decompose organic matter (Prambuddy et al. 2019). The variables of high BOD and COD illustrate that the high content of organic matter and chemicals that require large amounts of oxygen for the decomposition process. Organisms that have a high sensitivity to change will find it difficult to survive due to a decrease in DO content caused by high BOD and COD (Nishat et al. 2023). Livestock waste also contributes to the pollution that occurs in Seketak River. Livestock waste in the form of manure will produce ammonia. Ammonia from animal waste has the potential to become nitrite through the oxidation process by microorganisms in water. The process is one of the stages in the nitrification process that serves to maintain water stability (Hou et al., 2013). Industrial and domestic waste containing heavy metals such as iron and lead also cause the low water quality status of Seketak River. The location of Seketak River adjacent to the highway is also a factor in the high concentration of lead in the waters. Lead particles come from vehicles that emit smoke, then settle into the soil which is later exposed to rainwater and enters the water. High lead levels in water samples were found in locations adjacent to bus stations (Le et al., 2019).

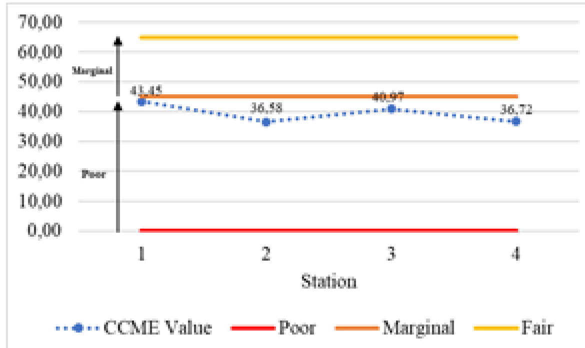


Figure 4. Water Quality Status of Seketak River Based on CCME- WQI Method

3.2.2 Pollution Load of Seketak River

Based on the analysis of the pollution load in the Seketak River as a whole, there are 5 variables that exceed the maximum pollution load. This indicates that the waters have been polluted. The COD variable at station 3 became the highest pollution load because it exceeded the maximum pollution load of 4,659.705 kg/day. BOD at station 3 is also the variable that has the second largest pollution load level by exceeding the maximum pollution load of 4,057,610 kg/day. The actual pollution load of BOD at station 2 is also high because it has exceeded the maximum pollution load of 1,333,599 kg/day.

Industrial waste, domestic waste, and livestock activities are the main sources of high organic compounds in the Seketak River that cause high COD and BOD pollution loads. Generally, domestic and industrial waste is the largest producer of waste that causes high COD concentrations (Wang et al., 2020). Household waste in the form of detergents, food waste, cleaners cause high COD concentrations. In addition, the decomposition process of livestock manure such as chicken, cow, and camel also contributes to the increase in COD concentrations in Seketak River. High concentrations of COD have the potential to cause mass mortality of aquatic biota, due to depletion of dissolved oxygen stocks. High COD values that exceed the quality standards set for waters indicate pollution that could potentially harm the environment (Ramayanti and Amna, 2019).

Domestic waste from settlements, student boarding houses, and shops causes a high BOD pollution load. High organic waste causes waters to have to decompose more organic matter, causing excess oxygen demand. Increased BOD can also be caused by aquatic plants or leaves that are decomposed by aquatic microorganisms (Ali et al., 2022). High BOD has the potential to cause a decrease in dissolved oxygen levels that interfere with the life of aquatic biota. High BOD concentrations cause the availability of dissolved oxygen to decrease, damaging aquatic habitats and biodiversity (Vigiak et al., 2019). Decreased dissolved oxygen concentrations can cause stress in organisms due to lack of oxygen and cause the death of aquatic biota and disrupt the balance of aquatic ecosystems. Low DO levels are also related to high temperatures in the waters. This occurs due to an increase in molecular vibrations, causing a decrease in the intermolecular space between water molecules. Therefore, the amount of DO is higher in cold water and lower in warm water (Khani and Rajaee, 2016).

CONCLUSION

The water quality status of Seketak River analyzed using the CCME-WQI method shows that all stations are in poor condition with a score of station 1 of 43.552, station 2 of 36.579, station 3 of 40.968, and at station 4 of 36.721. The station with the worst quality was recorded at station 2 which is thought to be the largest contribution of pollutants from domestic waste (residential areas, student boarding houses, and shops), thus station 2 is more polluted than stations 1, 3 and 4.

The pollution load of Seketak River shows that there are several variables that exceed the maximum pollution load including Nitrite, BOD, COD, iron, and lead, with the largest contribution of COD at station 3 because it exceeds the maximum pollution load of 4,659.705 kg/day. The poor condition of the waters in Seketak River is thought to be due to WWTP management that has not been implemented at the household scale, and exacerbated by waste from industry and livestock.

ACKNOWLEDGMENT

Grateful acknowledgment is made to LPPM Diponegoro University for the grant of the Community Service Activity of the Science and Technology Scheme for Undip Bangalore Desire (IDBU) funded in addition to the state budget (in addition to the state budget) of Diponegoro University which has financed this community service and research with SPK Number: 974-06/UN7.D2/PM/IX/2024.

REFERENCES

[1] Ali, B., Anuska, dan Mishra, A. 2022. Effects of dissolved oxygen concentration on freshwater fish: A review. International Journal of Fisheries and Aquatic Studies, 10(4): 113-127. https://doi.org/10.22271/fish.2022.v10.i4b.2693

[2] Alisa, C. A. G., Albirqi P., M. S., Faizal, I. 2020. Kandungan timbal dan kadmium pada air dan sedimen di perairan Pulau Untung Jawa, Jakarta. Jurnal Akuatika Indonesia, 6(2): 81-87.

[3] Anggraini, I. M., & Syahwanti, H. 2022. Pemetaan Sebaran Kandungan Tingkat Keasamaan (pH) Air Sungai Mahap Kabupaten Sekadau. E-Journal Teknologi Infrastruktur, 1(1): 1 – 6.

[4] Bahri, S., Harlianto, B., Saputra, H. E., Putra, A. H., Sariyanti, M. 2020. Analisis Faktor Abiotik Sumber Air Sumur di Lingkungan Kawasan Pesisir Pantai: Studi Kasus Kawasan Kampus Universitas Bengkulu. BIOEDUSAINS: Jurnal Pendidikan Biologi dan Sains, 3(2): 186-194. https://doi.org/10.31539/bioedusains.v3i2.1774.

[5] Brennan, C. E., Blanchard, H., & Fennel, K. 2016. Putting Temperature and Oxygen Thresholds of Marine Animals in Context of Environmental Change: A Regional Perspective for the Scotian Shelf and Gulf of St. Lawrence. PLoS ONE, 11(12): 1-27. https://doi.org/10.1371/journal.pone.0167411

[6] Bundschuh, J., Schneider, J., Alam, M. A., Niazi, N. K., Herath, I., Parveze, F., Tomaszewska, B., Guilherme, L. R. G., Maity, J. P., López, D. L., Cirelli, A. F., Pérez-Carrera, A., Morales-Simfors, N., Alarcón-Herrera, M. T., Baisch, P., Mohan, D., & Mukherjee, A. 2021. Seven potential sources of arsenic

pollution in Latin America and their environmental and health impacts. Science of the Total Environment, 780: 2-29. https://doi.org/10.1016/j.scitotenv.2021.146274

[7] Canadian Council of Ministers of the Environment. 2017. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index, User's Manual – 2017 Update*. In: *Canadian Environmental Quality Guidelines, 1999*. Canadian Council of Ministers of the Environment, Winnipeg.

[8] Elassassi, Z., Ougrad, I., Bedoui, I., Kara, M., El Bouch, M., Assouguem, A., Fadli, M., Almeer, R., Mohamed, H.R.H., & Peluso, I. 2022. Spatial and Temporal Variations of the Water Quality of the Tiflet River, Province of Khemisset, Morocco. Water, 14(12): 1 -16. https://doi.org/10.3390/w14121829

[9] Gao, Q., Li, Y., Cheng, Q., Yu, M., Hu, B., Wang, Z., Yu, Z. 2016. Analysis and assessment of the nutrients, biochemical indexes and heavy metals in the Three Gorges Reservoir, China, from 2008 to 2013. Water Research, 92: 262-274. https://doi.org/10.1016/j.watres.2015.12.055

[10] Hudiyah, M., & Saptomo, S. K. 2019. Analysis of water quality of water distribution channels in new building of Faculty of Economics and Management Bogor Agricultural University (IPB). JSIL Jurnal Teknik Sipil dan Lingkungan, 4(1): 13-24.

[11] Hou, J., Song, C., Cao, X., Zhou, Y. 2013. Shifts between ammonia-oxidizing bacteria and archaea in relation to nitrification potential across trophic gradients in two large Chinese lakes (Lake Taihu and Lake Chaohu). Water Research, 47(7): 2285–2296. https://doi.org/10.1016/j.watres.2013.01.042.

[12] Ishak, N. I., Mahmudah, Kasman, Ermayanti Ishak, I. J. Effendy, L. Fekri. 2023. Analisis kandungan logam berat pada air Sungai Martapura, Provinsi Kalimantan Selatan tahun 2022. Jurnal Sains dan Inovasi Perikanan, 7(1): 35-41.

[13] Khani, S., dan Rajaee, T. 2016. Modeling of dissolved oxygen concentration and its hysteresis behavior in rivers using wavelet transform-based hybrid models. Clean - Soil, Air, Water, 45(2): 1 – 18. 1500395

[14] Kim, J.-H., Kang, J.-C. 2015. The lead accumulation and hematological findings in juvenile rock fish Sebastes schlegelii exposed to the dietary lead (II) concentrations. Ecotoxicology and Environmental Safety, 115: 33–39. https://doi.org/10.1016/j.ecoenv.2015.02.009

[15] Kumar, A., Kumar, A., Cabral-Pinto, M.M.S., Chaturvedi, A.K., Shabnam, A.A., Subrahmanyam, G., Mondal, R., Gupta, D.K., Malyan, S.K., Kumar, S.S., Khan, S.A., Yadav, K.K. 2020. Lead Toxicity: Health Hazards, Influence on Food Chain, and Sustainable Remediation Approaches. International Journal of Environmental Research and Public Health, 17(7): 2179. https://doi.org/10.3390/ijerph17072179.

[16] Le, Q. H., Tran, D. D., Chen, Y.-C., & Nguyen, H. L. 2019. Risk of lead exposure from transport stations to human health: A case study in the Highland province of Vietnam. Toxics, 7(3): 1 – 13. https://doi.org/10.3390/toxics7030048

[17] Lee, J.-W., Choi, H., Hwang, U.-K., Kang, J.-C., Kang, Y. J., Kim, K. I., & Kim, J.-H. (2019). Toxic effects of lead exposure on bioaccumulation, oxidative stress, neurotoxicity, and immune responses in fish: A review. Environmental Toxicology and Pharmacology, 68, 59-74. https://doi.org/10.1016/j.etap.2019.03.010

[18] Mutmainah, A., Sulardiono, B., Rahman, A. 2022. Analisis Status Mutu Air Perairan Anak Sungai Bogowonto, Yogyakarta. Jurnal Pasir Laut, 6(1): 33-42.

[19] Napitupulu, R. T., Putra, M. H. S. 2024. Pengaruh BOD, COD dan DO terhadap lingkungan dalam penentuan kualitas air bersih di Sungai Pesanggrahan. CIVeng, 5(2): 79-82.

[20] Nasution, D.Y., Hasibuan, N.W., Nasution, R.M., Ramadhani, F. 2023. Pengaruh Perubahan Suhu Panas Media Air Terhadap Membuka dan Menutup Operkulum pada Ikan Mas. Journal Scientific of Mandalika (JSM), 4(2) 1 – 5.

[21] Nemati, M., Hamidi, A., Maleki Dizaj, S., Javaherzadeh, V., & Lotfipour, F. 2016. An Overview on Novel Microbial Determination Methods in Pharmaceutical and Food Quality Control. Advanced Pharmaceutical Bulletin,

6(3): 301-308. https://doi.org/10.15171/apb.2016.042

[22] Neno, A. K., H. Harijanto dan A. Wahid. 2016. Hubungan Debit Air dan Tinggi Muka Air di Sungai Lambagu Kecamatan Tawaeli Kota Palu. Warta Rimba. 4(2): 1-8.

[23] Nishat, A., Yusuf, M., Qadir, A., Ezaier, Y., Vambole, V., Khan, M. I., Moussah, S. B., Kamyabi, H., Sehgal, S. S., Prakash, C., Yang, H. H., Ibrahim, H., Eldin, S. M. 2023. Wastewater treatment: A short assessment on available techniques. Alexandria Engineering Journal, 76: 505-516. https://doi.org/10.1016/j.aej.2023.06.054

[24] Olivianti, A., Abidjulu, J., & Koleangan, H. S. J. 2016. Dampak Limbah Peternakan Ayam Terhadap Kualitas Air Sungai Sawangan Di Desa Sawangan Kecamatan Tombulu Kabupaten Minahasa. Chem. Prog., 9(2): 45 – 49.

[25] Pakpahan, R. A., Supit, C. J., & Pratasis, P. A. K. 2023. Studi Kualitas Air Sungai Sario Di Kota Manado Dengan Metode Model Dinamis. TEKNO, 21(85): 1301 - 1311.

[26] Panagopoulos, Y., Alexakis, D. E., Skoulikidis, N. T., Laschou, S., Papadopoulos, A., dan Dimitriou, E. 2022. Implementing the CCME Water Quality Index for the Evaluation of the Physicochemical Quality of Greek Rivers. Water, 14(2738). https://doi.org/10.3390/w14172738

[27] Prambudy, H., Supriyatin, T., & Setiawan, F. 2019. The testing of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) of river water in Cipager, Cirebon. IOP Conf. Series: Journal of Physics: Conf. Series, 1360(1): 1-6. https://doi.org/10.1088/1742-6596/1360/1/012010

[28] Pramleonita, M., Yuliani, N., Arizal, R., & Wardoyo, S. E. 2018. Parameter Fisika dan Kimia Air Kolam Ikan Nila Hitam (Oreochromis niloticus). Jurnal Sains Natural Universitas Nusa Bangsa, 8(1): 24-34.

[29] Pribadi, R. N., Zaman, B., Purwono. 2016. Pengaruh luas penutupan kiambang (Salvinia molesta) terhadap penurunan COD, amonia, nitrit, dan nitrat pada limbah cair domestik (grey water) dengan sistem kontinyu. Jurnal Teknik Lingkungan, 5(4): 1-10

[30] Ramadhan, R., Yusanti, I. A. 2020. Studi Kadar Nitrat dan Fosfat Perairan Rawa Banjiran Desa Sedang Kecamatan Suak Tapeh Kabupaten Banyuasin. Jurnal Ilmu-ilmu Perikanan dan Budidaya Perairan, 15(1): 37-41.

[31] Ramayanti, D. dan Amna, U. 2019. Analisis Parameter COD (Chemical Oxygen Demand) dan pH (potential Hydrogen) Limbah Cair di PT. Pupuk Iskandar Muda (PT. PIM) Lhokseumawe. Quimica: Jurnal Kimia Sains dan Terapan, 1(1): 16-21.

[32] Rani, D., dan Afdal. 2020. Identifikasi Pencemaran Air Sungai Batanghari Di Kecamatan Sitiung Kabupaten Dharmasraya Berdasarkan Tinjauan Fisik dan Kimia. Jurnal Fisika Unand (JFU), 9(4): 510-516. https://doi.org/10.25077/jfu.9.4.510-516.2020

[33] Rejito, A. 2019. Analisis Kadar Nitrit dalam Air Media Pemeliharaan Larva Ikan Kerapu Bebek Setelah Proses Aerasi. International Journal of Applied Chemistry Research, 1(2): 40. https://doi.org/10.23887/ijacr-undiksha

[34] Setyowati, D. L. 2008. Antisipasi Penduduk dalam Menghadapi Banjir Kali Garang Kota Semarang. Forum Ilmu Sosial, 35(2): 171 – 181.

[35] Sinaga, M. P., Siburian, D. T. E., & Zega, E. K. 2024. The Impact of Total Suspended Solid (TSS) and Containing Water Chlorophyll-A on the Fertility Level of Jakarta Bay Waters Using Technology of Google Earth Engine (GEE) Clouds. Jurnal Ilmiah Platax, 12(2): 32-44. https://doi.org/10.35800/jip.v10i2.55236

[36] Sugianti, Y., dan Astuti, L.P. 2018. Respon Oksigen Terlarut Terhadap Pencemaran dan Pengaruhnya Terhadap Keberadaan Sumber Daya Ikan di Sungai Citarum. Jurnal Teknologi Lingkungan, 19(2): 203-212.

[37] Supriatna, M., Mahmudia, M., Musa, M., & Kusriania. 2020. Hubungan pH dengan Parameter Kualitas Air pada Tambak Intensif Udang Vannamei (Litopenaeus vannamei). Journal of Fisheries and Marine Research, 4(3): 368-374.

[38] Tungka, A. W., Haeruddin, Ain, C. 2016. Konsentrasi Nitrata dan Ortofosfat di Muara Sungai Banjir Kanal Barat dan Kaitannya dengan Kelimpahan Fitoplankton Harmful Alga Blooms (HABs). Saintek Perikanan, 12(1): 40-46.

[39] Utama, L., Saidi, A., Berd, I., Mizwar, Z. 2018. Kajian Morphometri Pada Daerah Aliran Sungai (DAS) Batang Kuranji Terhadap Debit Banjir. Jurnal Sains dan Teknologi, 1(1): 65-79.
[40] Vigiak, O., Grizzetti, B., Udias-Moinelo, A., Zanni, M., Dorati, C., Bouraoui, F., dan Pistocchi, A. 2019. Predicting bioChemical Oxygen Demand in European freshwater bodies. Science of the Total Environment, 666: 1089–1105. https://doi.org/10.1016/j.scitotenv.2019.02.252
[41] Wisha, U. J., M. Yusuf, dan L. Maslukah. 2016. Kelimpahan fitoplankton dan konsentrasi tss sebagai indikator penentu kondisi perairan Muara Sungai Porong. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 9(2), 122 – 129.
[42] Wu, Z., Zhang, D., Cai, Y., Wang, X., Zhang, L., Chen, Y. 2017. Water quality assessment based on the water quality index method in Lake Poyang: The largest freshwater lake in China. Scientific Reports, 7: 1-10. https://doi.org/10.1038/s41598-017-18285-y
[43] Zainuri, M., Indriyawati, N., Syarifah, W., Fitriyah, A. 2023. Korelasi Intensitas Cahaya Dan Suhu Terhadap Kelimpahan Fitoplankton Di Perairan Estuari Ujung Piring Bangkalan. Buletin Oseanografi Marina, 12(1): 20-26. https://doi.org/10.14710/buloma.v12i1.44763.