JSSEW
Journal of Sustainability, Society, and Eco-Welfare
JSSEW 2(1): 29-48
ISSN 3025-1524

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Biophysics indicators as the sustainable strategy for river pollution control: Case study in Jangkok River, Mataram City, West Nusa Tenggara

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Received Date: June 25, 2024 Revised Date: July 29, 2024 Accepted Date: July 30, 2024

ABSTRACT

Background: Sungai Jangkok is one of those considered heavily polluted in West Nusa Tenggara/Nusa Tenggara Barat (NTB), Indonesia. The Biochemical Oxygen Demand (BOD) value has exceeded the Class II water quality standard, and according to the Family Biotic Index (FBI) value, the river falls under the category of heavy organic pollution. The research objective is to realize sustainable management of the Jangkok Watershed by its river functions by implementing pollution control strategies. **Methods:** Data was collected using questionnaires and interviews with the public and stakeholders (government and NGOs). Water quality data was obtained from DLHK NTB and DLH Mataram City, and sampling was carried out using the composite sample technique. The methods employed were STORET, QUAL2Kw, logistic regression, and SWOT. **Findings:** The research findings indicate that, in general, the Jangkok River in Mataram City falls into the heavily polluted category from 2015 to 2022, with an average STORET score of -79.25. Moreover, the pollution loads of BOD, COD, and TSS entering the river have exceeded the pollution-carrying capacity. The condition is influenced by several factors, including the less favorable perception of pollution status (67%) and the usefulness of the river (59%) by the community. Additionally, the persistent behavior of littering and defecating in the river (23%), inadequate preventive practices (59%), insufficient wastewater disposal facilities (40%), and improper waste management (58%) are contributing factors. Moreover, houses backing up to the river (59%) also play a role in the current condition. Some causes are the need for more synergy across administrative regions between stakeholders, the absence of law enforcement for the community, dependency on the government budget for work programs, and the lack of incentives. **Conclusion:** The conclusion of this research suggests that the most effective strategy for taking is to develop a program for reducing pollutant loads that is integrated across districts and cities, integrated across agencies with various levels of authority, integrated with the community, and by the river's actual conditions and the socioeconomic community. **Novelty/Originality of this Study:** This study provides a novel approach by integrating quantitative water quality modeling (QUAL2Kw) with community behavior analysis to develop a sustainable and comprehensive strategy for controlling river pollution in the Jangkok watershed, Mataram City.

KEYWORDS: behavior; involvement; perception; pollution control; river water quality; stakeholder settlement.

1. Introduction

The degradation of river water quality has become a global concern, particularly in developing countries where more than 80% of wastewater is discharged directly into rivers without treatment (Hou et al., 2020; Yu et al., 2019). According to Hairan et al. (2021), river pollution in Indonesia is generally caused by unsustainable water management practices.

Cite This Article:
Haryono, I., Agustina, H., & Soesilo, T. E. B. (2024). Biophysics indicators as the sustainable strategy for river pollution control (case study in Jangkok River, Mataram City, West Nusa Tenggara). *Journal of Sustainability, Society, and Eco-Welfare*, *2*(1), 29-48. https://doi.org/10.61511/jssew.v2i1.2024.943

Rapid population growth, urbanization, and economic development are the primary drivers of river pollution (Jiang et al., 2021; Kim & Ryu, 2020). Anthropogenic activities triggered by urbanization further contaminate global aquatic ecosystems, often leading to higher river pollution levels in urban areas than in suburban and rural regions (Al-Omari et al., 2019; Mgelwa et al., 2020; Indriyani et al., 2021). Agricultural and industrial activities that support the economy also play a significant role in river pollution (Guerreiro et al., 2020; Liu et al., 2020, Horton & Barnes, 2020).

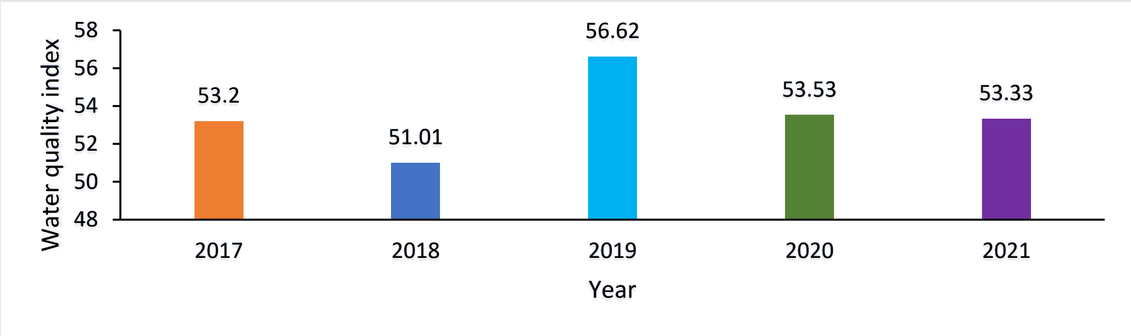


Fig. 1. Indonesia water quality index 2017-2021
(KLHK, 2019)

River pollution has detrimental impacts on the environment and human health, including the extinction of aquatic biota (Elfidasari et al., 2020; Kang et al., 2020; Hlordzi et al., 2020), decreased aesthetic value of the environment (Samsudin et al., 2017), flooding, and decreased human health quality (Garg et al., 2018; Liu et al., 2020). Additionally, river pollution can adversely affect ecosystems connected to river mouths, such as beaches, bays, coral reefs, and offshore areas (Susilowati et al., 2020). For instance, severe pollution from urban domestic waste in rivers has caused various environmental problems in Daya Bay in the South China Sea (Xiong et al., 2021). In Southeast Asia, coral reefs have been impacted by plastic pollution caused by river pollution. Mangrove habitats have more potential for plastic pollution exposure than others (seagrass, salt marshes, or coral reefs) due to their proximity to river mouths (Harris et al., 2021).

The government has implemented a pollution control program focused on water quality standards in Indonesia. However, this program has not significantly improved water quality or changed societal behavior, as indicated by the Indonesian Water Quality Index, which has not shown significant improvement and even declined in 2021 (Figure 1). The failure of the pollution control program is also evident from the increasing number of heavily polluted rivers and the decreasing number of lightly polluted rivers (Figure 2) (based on a sample of 98 rivers in Indonesia) (KLHK, 2019).

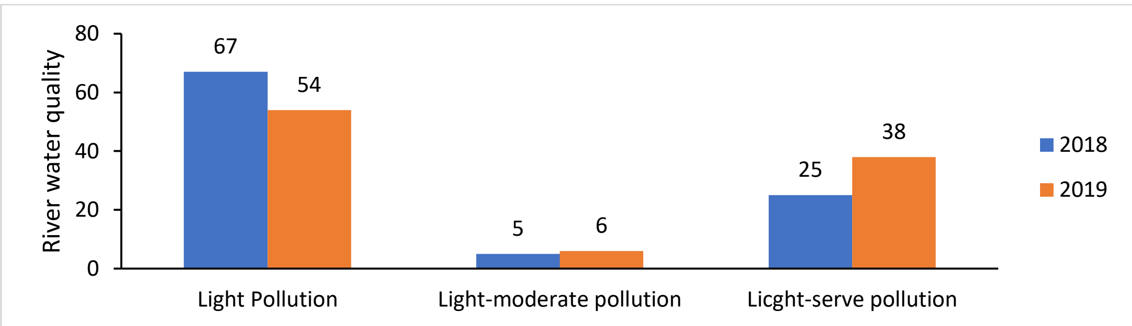


Fig. 2. Change in quality status of river water quality 2018-2019 based on 98 rivers in Indonesia
(KLHK, 2019)

West Nusa Tenggara (NTB) Province is one of the regions in Indonesia experiencing moderate to severe river water pollution. The primary cause of river water pollution in NTB is the community's use of water bodies for open defecation and the disposal of solid and liquid waste (DLHK NTB, 2019). Mataram City is one of the most densely populated urban areas in NTB, traversed by four rivers: Brenyok River, Midang River, Ancar River, and Jangkok River. These rivers originate near Mount Rinjani and flow into the Lombok Strait (BAPPEDA Kota Mataram, 2018). The common problem with these rivers is the decline in water quality caused by increasing residential settlements along the riverbanks, which discharge their wastewater directly into the water bodies (Dharmawibawa, 2019).

Jangkok River is one of the most heavily polluted rivers in NTB (BPS, 2019). It flows through West Lombok Regency in the upstream area and Mataram City in the downstream area, with a length of 47.106 km and an area of 170.298 km^2 (Faqih & Fitasari, 2020). The middle to downstream sections of the Jangkok River (Mataram City area) experience severe pollution. According to the 2019 NTB DLHK data, the river's BOD values in the middle to downstream sections exceeded the Class II water quality standards, reaching far above the Class IV standard of 141.6 mg/L in July. High BOD values indicate poor water quality and high levels of organic pollution (Belinawati et al., 2018; Djoharam et al., 2018; Hlordzi et al., 2020).

Direct observations and physical tests have shown that Jangkok River is polluted, with highly turbid water, a pungent odor, and high temperatures (Idrus, 2015). The main factor contributing to the pollution of the Jangkok River is the unmanaged disposal of household waste and wastewater (Idrus, 2015). This issue is influenced by the residential situation along the riverbanks, where many houses face away from the river, fostering a culture of indifference towards the river's importance. Consequently, residents often perceive the river as a place to dispose of waste (Kwon et al., 2019; Alfiyansyah, 2020; Jama et al., 2020).

The pollution of the Jangkok River is also suspected to be caused by the ineffective involvement of stakeholders in the river pollution control program (Herzog & Ingold, 2019). This includes poor waste management systems and weak law enforcement, as evidenced by the continued practice of direct waste disposal into the river by many residents. As the leading actor in pollution control programs, the government is crucial in improving water quality and changing societal behavior. However, a lack of concern for the negative impacts of river pollution on ecosystem degradation has led to poor law enforcement and insufficient community empowerment to maximize social benefits (Xu et al., 2020).

To address river pollution effectively, a sustainable strategy is required that incorporates biophysical indicators, such as river water quality and pollution load capacity, and social indicators, such as stakeholder involvement and community behavior. Modeling river water quality and assessing pollution load capacity can provide valuable insights for decision-making and developing proactive response plans (Albuquerque & Pelletier, 2019). Additionally, analyzing community perceptions and behavior towards the river can help identify social causes of pollution and inform strategies for community empowerment and behavior change (Syafri et al., 2020; Djuwita et al., 2021; Bouckaert et al., 2021).

2. Methods

This research was conducted in the Jangkok watershed, Mataram City. The location was chosen because it is the only river in NTB that the central government prioritizes regarding long-term water quality assessment. In addition, the Jangkok River was chosen because it passes through a densely populated residential area in the middle of Mataram City, which is the most populous urban area in NTB with a density of around 7940 people/km^2 (BPS NTB, 2020). The Jangkok River empties into the coast of Ampenan Beach. This beach is one of the beach tourism areas in Mataram City. Studying the Jangkok River is expected to reduce pollution that occurs on the beach.

The approach taken in this research is quantitative. This is because, in general, the type of data used is numerical, focuses on questioning the problem, and uses analytical methods. Quantitative methods are used to analyze the water quality and pollution load capacity of the Jangkok River, Mataram City. Quantitative methods are used to analyze the influence of community settlement conditions on the water quality of the Jangkok River, Mataram City and to develop a sustainable strategy for controlling the water pollution of the Jangkok River, Mataram City.

The target population of river water is part of the river in the administrative area of Mataram City (middle to downstream of Jangkok River). The data sources used are primary and secondary data with quantitative data properties and time series data from 2015-2022. Secondary data was obtained from DLHK NTB Province and DLH Mataram City. The authors used the STORET method in this study because there was sufficiently complete time series data. According to Ermawati & Hartanto (2017), using the pollution index method is usually caused by the lack of time series data because the STORET method requires complete data for determining water quality status. The weakness of the STORET method is that it is influenced by the number of parameters being compared (Sugiyarto et al., 2018). The steps for determining water quality status using the STORET method are in KEPMEN No.115/MENLH/2003 (Shaleh et al., 2021). The classification of water quality status based on the STORET method can be seen in Table 1.

Table 1. Water Quality Status Based on Score in STORET Method

No	Water quality status	Score
1	Meets quality standards	0
2	Mildly polluted	-1 s/d -10
3	Moderately polluted	-11 s/d -30
4	Severely polluted	≥ -31

(KEPMEN No.115/MENLH/2003)

2.1 QUAL2Kw methods

There are three analytical methods mentioned in PP No. 82/2001 on Water Quality Management and Water Pollution Control for pollution load-carrying capacity analysis: the Streeter-Phelps method, the mass balance method and the QUAL2E method. Recently, QUAL2E was developed into QUAL2Kw. In this research, the QUAL2Kw method was used. The calculation in the QUAL2Kw program uses Visual Basic for Application (VBA), which is implemented in Microsoft Excel (Saily & Setiawan, 2021). This method is the author's choice because it has the following advantages: 1) It can accurately show the dynamic development of the selected indicator parameters; 2) It is flexible because it can be used without knowing all the parameters involved as default value assumptions; 3) QUAL2Kw as a mathematical model only requires simple input parameters; 4) It offers a complete framework for surface water quality simulation, especially in places with scarce monitoring data (Albuquerque & Pelletier, 2019). QUAL2Kw is one of the most effective methods for water quality modeling (Antunes et al., 2018). The drawback of QUAL2Kw, according to Oliveira et al. (2012), is that the model results only sometimes represent the exact conditions in the river and are limited to showing information.

The process of calculating the pollution load capacity using the QUAL2Kw method begins by entering the calibration test data into the program. After collecting primary and secondary data, the input is collected in a worksheet using Microsoft Excel software (Chasna, 2016). The next step is to conduct a calibration test, where model formation is carried out through a trial and error process to produce a model that is close to the actual conditions (Mooselu et al., 2019; Saily & Setiawan, 2021). After the calibration test produces an appropriate model, the model is used for the validation test. However, if the model is still not appropriate, a recalibration test is carried out. The last stage is the validation test which is carried out to determine the suitability of the resulting model with the previously entered water quality data. The validation test can use Equation 1, and the model can be accepted and used if the RMSE value is ≤1 (Manalu, 2022).

$$RMSE = \sqrt{\frac{1}{n}[\sum_{n-1}^{n}(\frac{St-At}{At})^2]} \qquad \text{(Eq. 1)}$$

Where RMSE is the Root Mean Square Error, St is the simulated value at time t, At is the actual value at time t, and n is the number of observations.

After the model can be used based on the validation test, model simulations are carried out with several scenarios to see the river's response to the incoming pollution load and to get an idea of the nature and behavior of the pollution source. The next step is to calculate the Pollution Load (BP), which is the amount of pollutant elements in water or waste. BP per day can be calculated using Equation 2:

$$BP = \text{Discharge x Concentration} \quad \text{(Eq. 2)}$$

Finally, an analysis of the pollution load capacity conditions is carried out. The pollution load capacity conditions can be seen by reducing the maximum pollution load based on water quality standards with the existing pollution load (Saily & Setiawan, 2021).

3. Results and Discussion

3.1 Result

3.1.1 Water quality of Jangkok River, Mataram City

To get the latest information about the Jangkok River's water quality, the author used water quality monitoring data for 2022 from DLH Mataram City. Table 2 shows the results of water quality testing in October 2022. The table shows that the parameters that exceed the class II water quality standards are TSS, BOD, COD, Oil and fat, Dissolved iron, E. coli and Total Coliform.

Table 2. Water quality data of Jangkok River, Mataram City in October 2022

No	Paramter	Unit	Water Quality Standard Class II	Measurement Results		
				Upstream	Midstream	Downstream
Physical						
1	Temperature	^0C	Dev 3	25	25.6	28.65
2	TDS	mg/L	1000	39.71	42.71	49.52
3	TSS	mg/L	50	44	378	364
	Chemical					
1	PH		6-9	8.04	7.91	7.71
2	BOD	mg/L	3	2.62	2.95	3.06
3	COD	mg/L	25	86.22	76.57	83.68
4	DO	mg/L	4	6.08	6.18	5.38
5	Total Phosphate (as P)	mg/L	0.2	0.05	0.07	0.07
6	Nitrite (as N)	mg/L	0.06	0.005	0.015	0.023
7	Sulfate	mg/L	300	1	1	1
8	Fluoride	mg/L	1.5			
9	Chloride	mg/L	300	0.46	0.46	3.66
10	Oil and Grease	mg/L	1	3	3	2
11	Nitrate	mg/L	10	2.41	2.26	2.71
12	Total Detergent	mg/L	0.2	0.025	0.025	0.025
13	Cyanide	mg/L	0.02			
14	Dissolved Iron (Fe)	mg/L	0.3	5.66	0.83	0.78
15	Dissolved Lead (Pb)	mg/L	0.03	0.02	0.02	0.02
Biological						
1	*E. coli*	MPN/ 100 ml	1000	92000	92000	160000
2	Total Coliform	MPN/ 100 ml	5000	160000	160000	160000

(Mataram City Environmental Agency, 2022)

The source of TSS pollution can be organic and inorganic materials, while BOD, COD, Oil and fat, *E. coli* and Total Coliform come from domestic household waste. Dissolved iron can come from household and industrial activities. If connected to the condition of the research area, which is primarily residential with data on the results of parameters that exceed the quality standards, it can be identified that the source of pollution is domestic, primarily waste generated from community activities in the form of wastewater (faeces, used for bathing and washing), and garbage (cooking residue and used wrappers).

The water quality data in Table 2 can also show the areas that produce the highest pollution load. In Figure 3, it can be seen that the TSS parameter has the highest pollution load coming from the Upstream to Central area because the TSS value increases very significantly from the Upstream to Central point by 334 mg/L (759%) while the Central to Downstream area decreases by 14 mg/L (3.7%). The same thing happened with the BOD parameter; the highest pollution load occurred from the Upstream to Central point with an increase in BOD value of 0.33 mg/L (12.59%), while the Central to Downstream area also experienced an increase but more minor at 0.11 mg/L (3.73%). Different conditions occur in the COD parameter, and the highest pollution load comes from the Upstream area (the area before the Upstream point) with a BOD value of 86.22 mg/L, the highest compared to the Central and Downstream points. In the Upstream to Central area, there was a decrease in BOD value of 9.65 mg/L (11.19%), while in the Central to Downstream area, there was an increase of 7 mg/L (9.28%).

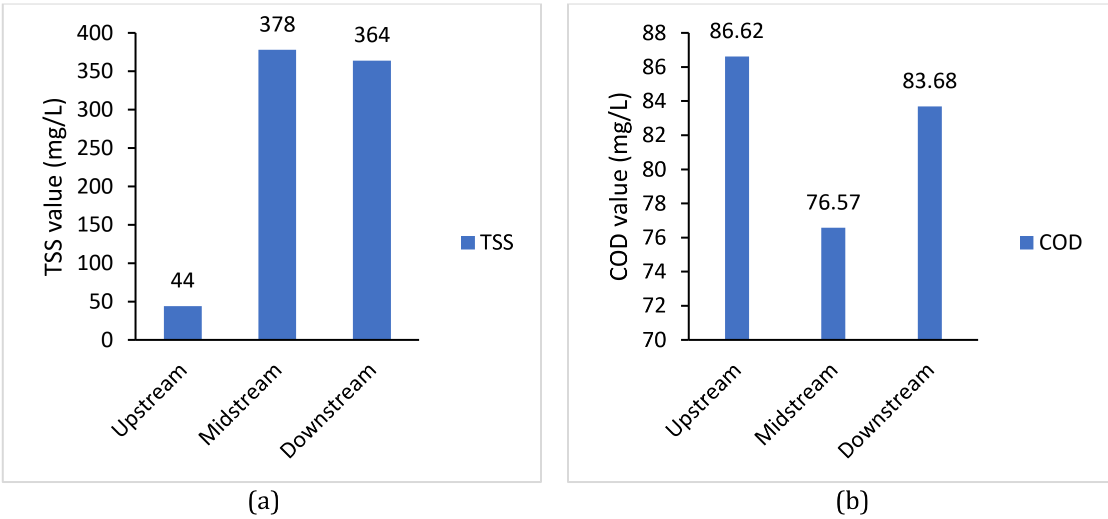


Fig. 3. Graph of parameter testing results in Jangkok River, Mataram City October 2022: (a) TSS; (b) COD

The parameters related to oil and fat, dissolved iron, E. coli, and total coliform can be seen in Figure 4. In the oil and fat parameter, the highest pollution load comes from the Upstream area, and the pollution load tends to decrease from the Central to the Downstream area. The same thing happened to the dissolved Iron (Fe) parameter; the highest pollution load came from the Upstream area with a dissolved Iron (Fe) value of 5.66 mg/L. The value decreased significantly by 4.83 mg/L (85%) from the Upstream to the Center point and decreased again from the Center to the Downstream point by 0.05 mg/L (6.02%). E. coli and Total Coliform parameters have similar conditions, with the highest pollution load coming from the Central to Downstream area with a parameter value of 160,000 MPN/100 mL. In the E. coli parameter, the high pollution load comes from the area before the Upstream and increases from the Upstream to the Downstream point with an E. coli value of 68,000 MPN/100 mL (74%). In the Total Coliform parameter, the high pollution load also comes from the area before the Upstream and does not increase or decrease in the Downstream area.

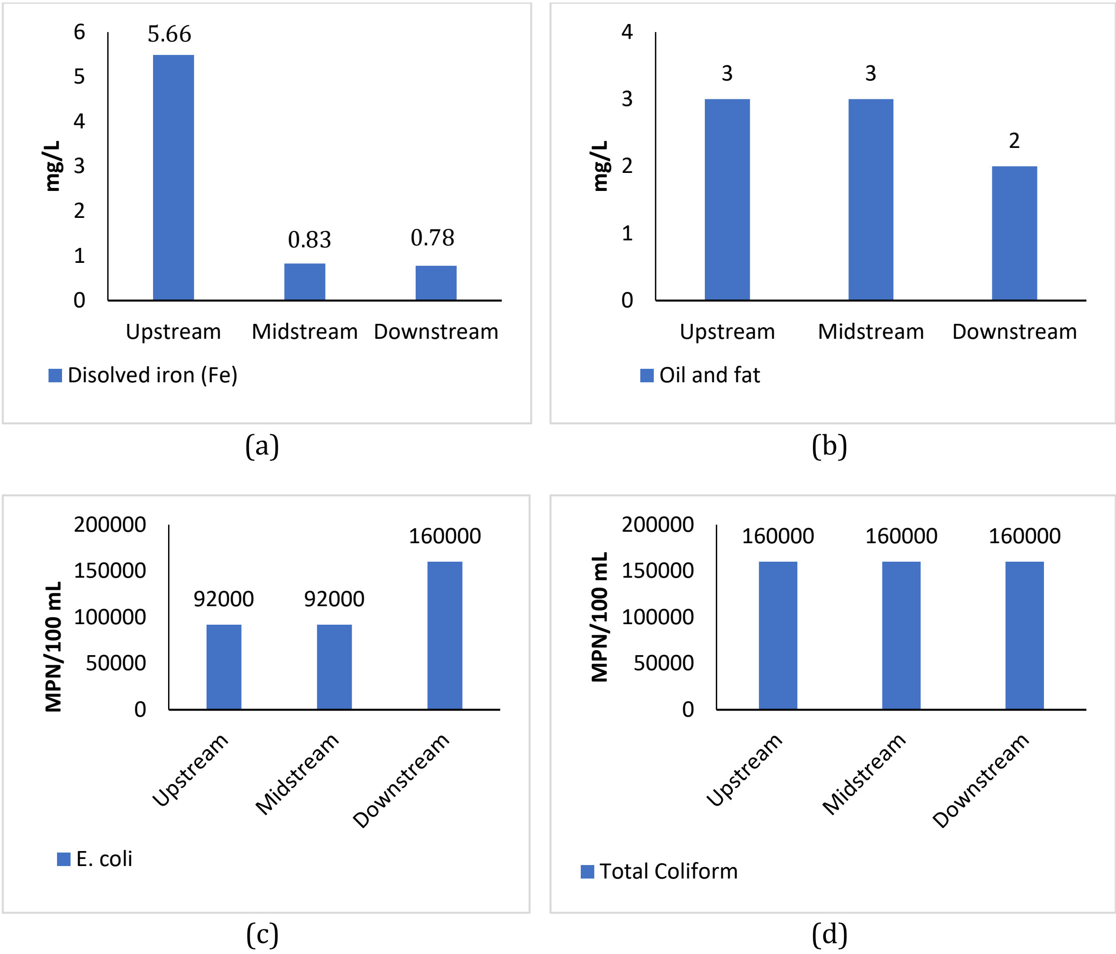
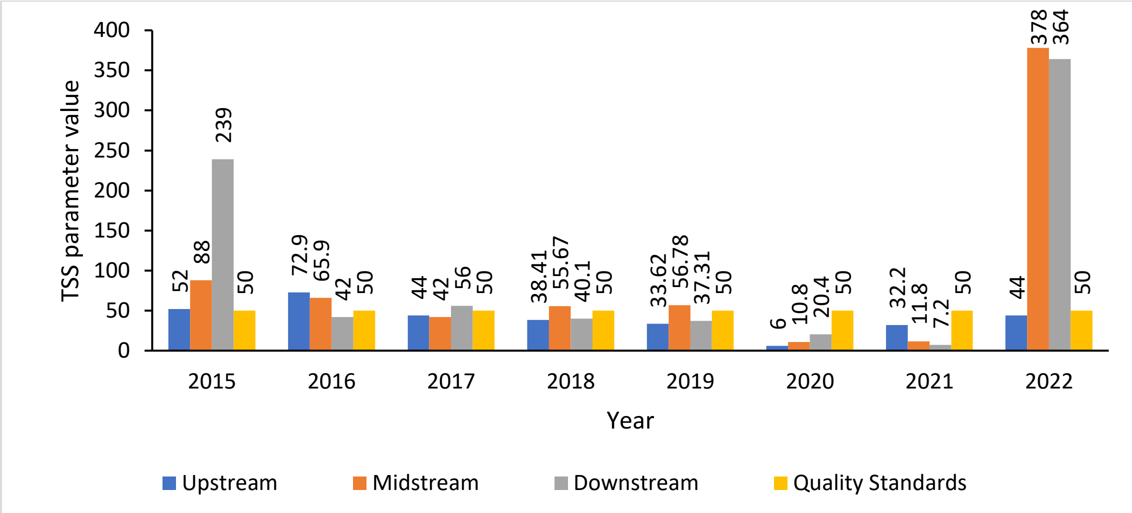


Fig. 4. Graph of Parameter Testing Results in Jangkok River, Mataram City October 2022: (a) Dissolved Iron (Fe); (b) Oil and fat; (c) E. coli; (d) Total Coliform.

To evaluate the long-term water quality of the Jangkok River, Mataram City, the maximum value of parameter test results for 2015-2022 was used. The evaluation was conducted on five parameters that consistently exceeded the class II water quality standards for 2015-2022: TSS, BOD, COD, E. coli and Total Coliform. Figure 5 shows the maximum values of TSS, BOD, and COD, while Figure 6 shows the maximum values of *E. coli* and Total Coliform. The maximum value of TSS at the Upstream point is consistently below the class II water quality standards from 2017-2022 with an average of 33.04 mg/L, while at the Middle and Downstream points, it tends to decrease until 2021. The success of pollution control for the TSS parameter occurred in 2020 and 2021 because the maximum value at the Upstream, Central and Downstream points was below the class II water quality standard. A significant increase in the maximum value of TSS occurred in 2022 at the Central and Downstream points of 366.2 mg/L (3,103%) and 356.8 mg/L (4,955%).

Different conditions occur in the BOD parameter, and the maximum value at the Upstream point consistently exceeds the class II water quality standards, with an average value of 4.45 mg/L from 2015 to 2022. The maximum value of the BOD parameter generally tends to decrease at the Upstream, Central, and Downstream points in 2015-2022. However, it has yet to fall below class II water quality standards consistently. For the COD parameter, the maximum value decreased significantly in 2018 but increased again in 2022. In 2019-2021, pollution control for the COD parameter was quite successful at the upstream, central and downstream points, with the maximum value below the class II water quality standard. The maximum value of COD increased significantly in 2022 at the Upstream, Central and Downstream points by 72.9 mg/L (547%), 58.93 mg/L (334%) and 63.09 mg/L (306%) respectively.



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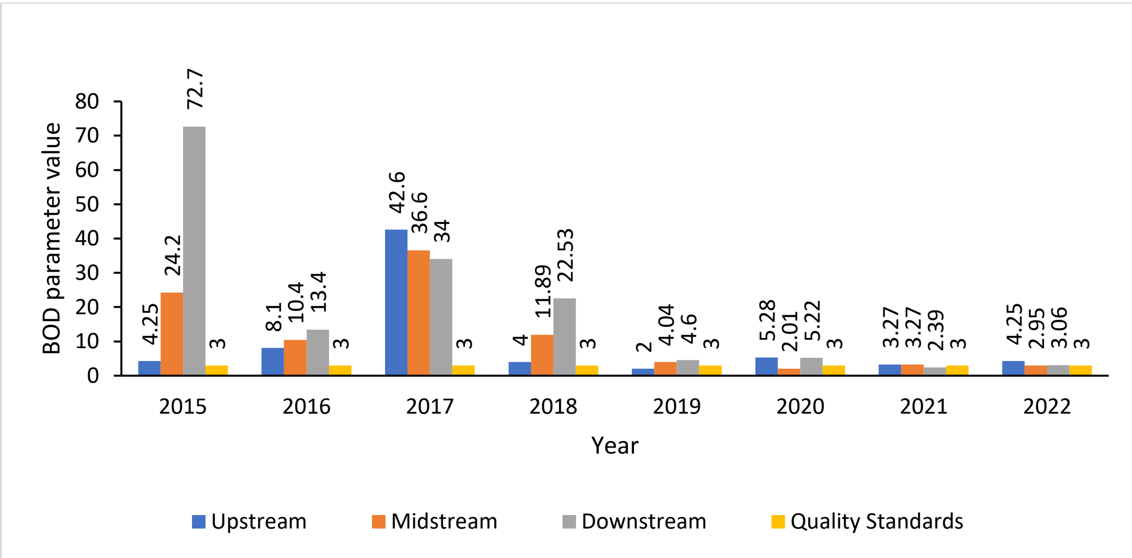

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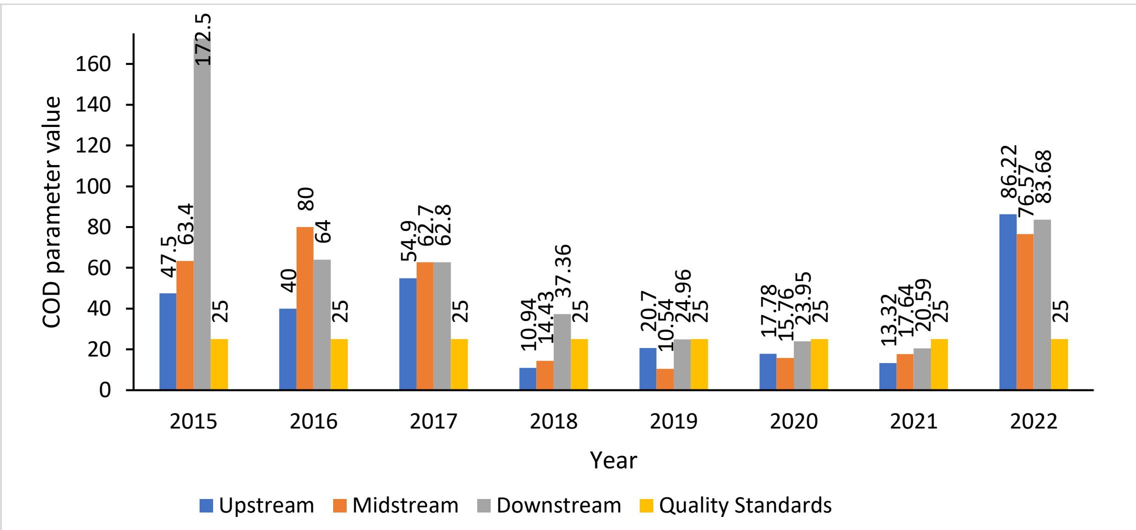
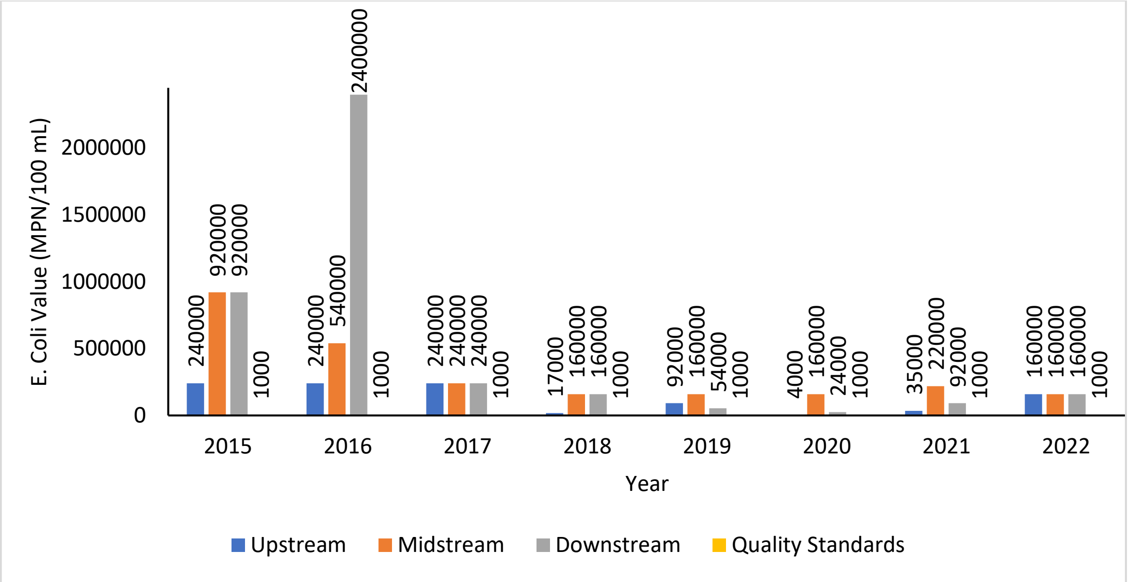


(c)

Fig. 5. Graph of Maximum Value of Parameter Testing Results in Jangkok River, Mataram City 2015-2022: (a) TSS; (b) BOD; (c) COD.

The maximum value of E. coli and Total Coliform parameters in 2015-2022 in Figure 6 is still very high and far above the class II water quality standards. A decrease in the maximum value occurred in 2017, and the lowest maximum value occurred in 2020 at the upstream point of 4000 MPN/100 mL for *E. coli* and 4700 MPN/100 mL for Total Coliform. The maximum value of Total Coliform is the only value that is below class II water quality standards.



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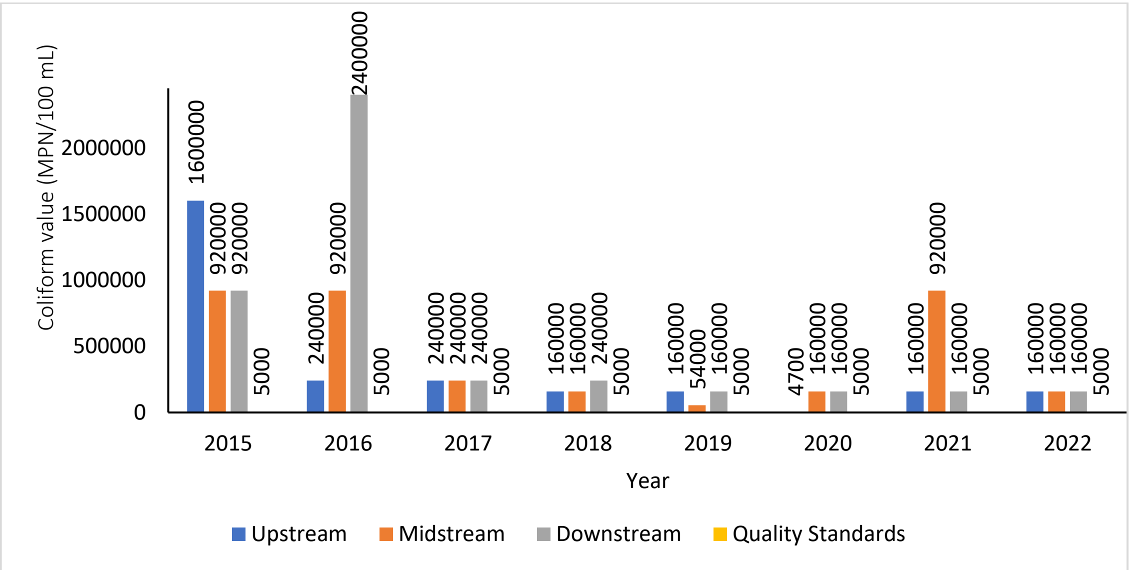


(b)

Fig. 6. Graph of Maximum Value of Parameter Testing Results in Jangkok River, Mataram City 2015-2022: (a) E. coli; (b) Total Coliform.

Evaluation of the overall and long-term water quality of the Jangkok River, Mataram City, was carried out by analyzing the water quality status using the STORET method. The results of the water quality status analysis are shown in Table 3. These results are processed from water quality testing data of Jangkok River, Mataram City, conducted by DLHK NTB in 2015-2017 and DLH Mataram City in 2018-2022. Based on these results, the Jangkok River, Mataram City, is in the heavily polluted category from 2015-2022 with an average STORET score of -79.25 and only in 2020 experiencing moderate pollution in the upstream section.

Table 3. Water Quality Status of Jangkok River, Mataram City 2015-2022

No	Year	Upstream		Midstream		Downstream	
		Score	Status	Score	Status	Score	Status
1	2015	-62	Heavily Polluted	-88	Heavily Polluted	-200	Heavily Polluted
2	2016	-58	Heavily Polluted	-65	Heavily Polluted	-65	Heavily Polluted
3	2017	-68	Heavily Polluted	-156	Heavily Polluted	-180	Heavily Polluted
4	2018	-52	Heavily Polluted	-60	Heavily Polluted	-196	Heavily Polluted
5	2019	-31	Heavily Polluted	-51	Heavily Polluted	-63	Heavily Polluted
6	2020	-25	Moderately Polluted	-40	Heavily Polluted	-68	Heavily Polluted
7	2021	-34	Heavily Polluted	-40	Heavily Polluted	-40	Heavily Polluted
8	2022	-58	Heavily Polluted	-54	Heavily Polluted	-148	Heavily Polluted

In this study, the water quality status of the Jangkok River, Mataram City, is determined based on the total score of the STORET method. Figure 7 shows that, in general, there is an increasing trend in scores in all parts of the Jangkok River, Mataram City, from 2015-2022. This means there has been an improvement in water quality compared to water quality in 2015. Based on the results of the scores in Table 3, at the Upstream, Central and Downstream points, there was an increase in scores with a percentage of 6%, 38%, and 26% from 2015-2022. A significant increase in score occurred in 2020 with percentages of 59%, 54%, and 66%, respectively. The low percentage of score increase is due to the decrease in score in 2022; even in the Downstream section, there was a significant decrease compared to 2021. This significant decrease in score can indicate the high water pollution of the Jangkok River, Mataram City, in 2022 in the downstream section.

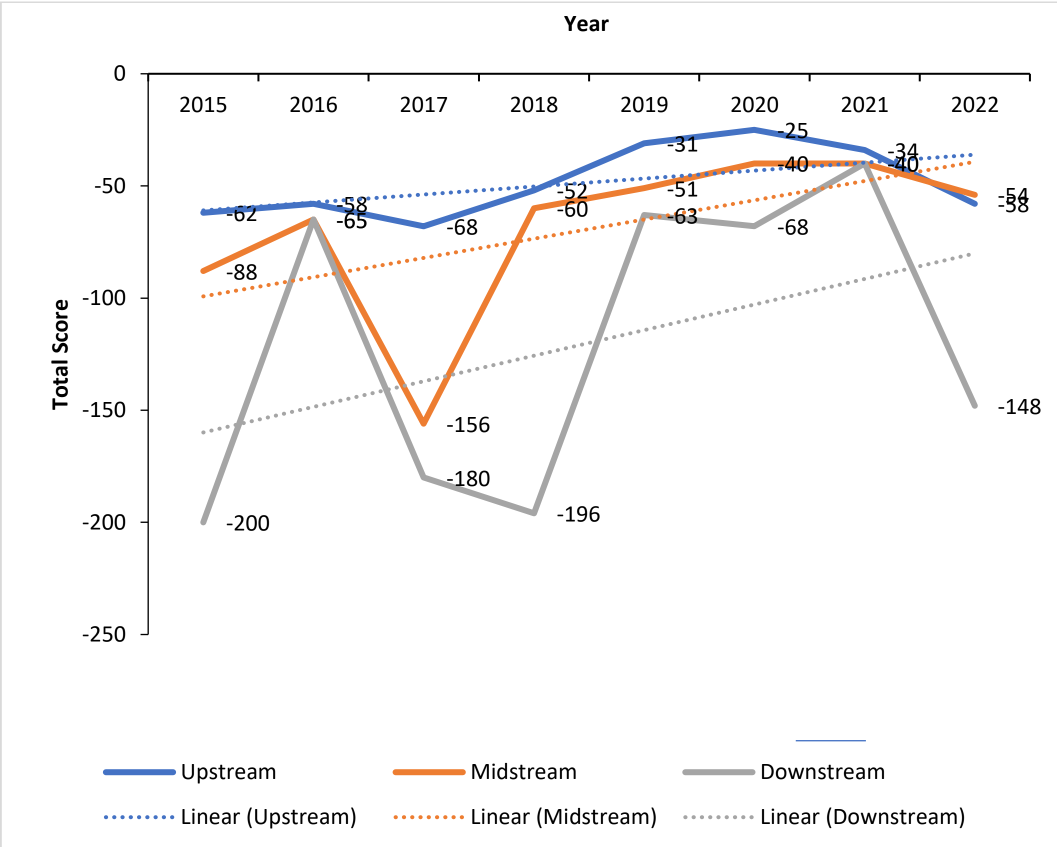


Fig. 7. Trend graph of total score of water quality status in Jangkok River, Mataram City

The number of scores from the STORET analysis on the Jangkok River, Mataram City, is influenced by the number of parameters that exceed the water quality standard II. The number of parameters is shown in Table 4. Parameters that exceed quality standards are determined based on the maximum, minimum, and average parameter values.

Table 4. List of parameters that exceed class ii water quality standard in Jangkok River, Mataram City 2015-2022

No	Year	Parameter (Total)		
		Upstream	Midstream	Downstream
1	2015	TSS, BOD, COD, Dissolved Iron, E. coli, and Total Coliform (7)	TSS, BOD, COD, DO, Total Phosphate, Dissolved Iron, E. coli, and Total Coliform (8)	TSS, BOD, COD, DO, Total Phosphate, Nitrite, Nitrate, Dissolved Iron, E. coli, and Total Coliform (10)
2	2016	TSS, BOD, COD, Total Phosphate, Dissolved Iron, E. coli, and Total Coliform (7)	TSS, BOD, COD, DO, Total Phosphate, Dissolved Iron, E. coli, and Total Coliform (8)	BOD, COD, Total Phosphate, Nitrite, Dissolved Iron, E. coli, and Total Coliform (7)
4	2018	BOD, Oil and Grease, Cyanide, E. coli, and Total Coliform (5)	BOD, Oil and Grease, Cyanide, E. coli, and Total Coliform (6)	TDS, BOD, COD, DO, Total Phosphate, Nitrite, Chloride, Oil and Grease, Cyanide, E. coli, and Total Coliform (11)
5	2019	DO, Nitrit, *E. coli*, dan Total Coliform (4)	SS, BOD, DO, Nitrite, Fluoride, Total Detergent, E. coli, and Total Coliform (8)	TDS, BOD, DO, Total Phosphate, Nitrite, Chloride, E. coli, and Total Coliform (8)
6	2020	BOD, Total Phosphate, and E. coli (3)	Total Phosphate, Nitrite, E. coli, and Total Coliform (4)	BOD, DO, Total Phosphate, Nitrite, Total Detergent, E. coli, and Total Coliform (8)
7	2021	BOD, E. coli, and Total Coliform (3)	BOD, Total Phosphate, E. coli, and Total Coliform (4)	DO, Total Phosphate, E. coli, and Total Coliform (4)
8	2022	BOD, COD, Oil and Grease, Dissolved Iron, E. coli, and Total Coliform (6)	TSS, COD, Oil and Grease, Dissolved Iron, E. coli, and Total Coliform (6)	TSS, BOD, COD, DO, Total Phosphate, Nitrite, Oil and Grease, Dissolved Iron, E. coli, and Total Coliform (10)

The highest number of parameters exceeding quality standards occurred in the downstream section in 2018, namely 11 parameters, while the lowest number occurred in the upstream section in 2020 and 2021, namely three parameters. This number is based on the score results in Table 4, which show that 2020 obtained the highest score, was categorized as moderately polluted, and had the most significant percentage of water quality improvement. The suitability can also be seen from the trend of the number of parameters exceeding water quality standards, which has decreased. This is inversely proportional to the number of increased STORET analysis scores. This means that the fewer parameters that exceed the quality standards, the greater the score of the STORET analysis results. When viewed from changes in the number of parameters that exceed water quality standards from 2015-2022, there has been no significant change in the number. Although there was a decrease in the number of parameters in 2020 and 2021, it increased again in 2022.

The author took primary data to obtain information related to differences in water quality during the day and evening. Sample test results can be seen in Table 5. The Table shows that the parameters TSS, COD, and BOD do not exceed the class II water quality standards, while Fecal Coliform and Total Coliform far exceed them. These results are more or less the same as the previous results because the sampling was done during the rainy season (December 2022).

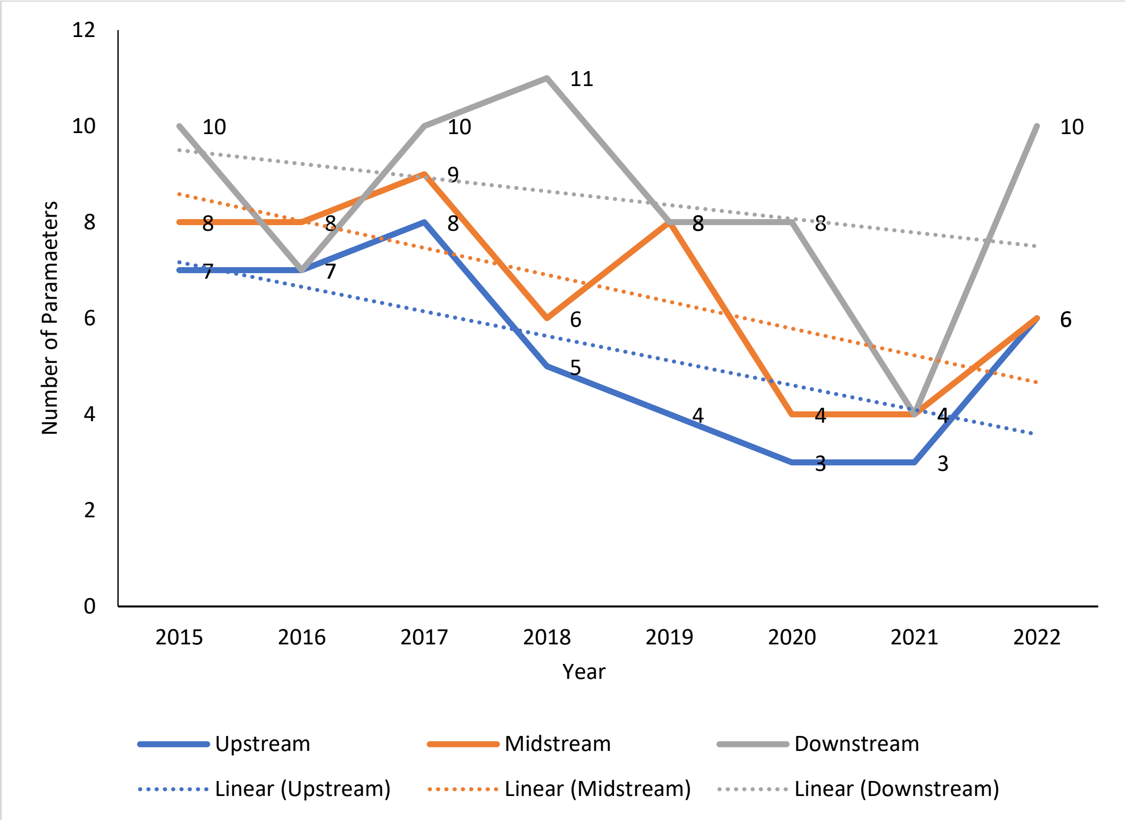


Fig. 8. Trend graph of the number of parameters that exceed class ii water quality standards in Jangkok River, Mataram City

Table 5 shows an increase in the concentration values of the parameters from afternoon to evening. The most significant increase occurred in Total Coliform and Fecal Coliform parameters. This can indicate that activities that produce total coliform and fecal coliform occur more often in the afternoon. The significant increase in Fecal Coliform values is relevant to the habits of people in the study area who carry out toilet activities in the afternoon. It can also be seen that there is a high difference between the Total Coliform and Fecal Coliform values in the afternoon, namely 970,000 MPN/100 ml, which indicates that Total Coliform is sourced from not only human feces (Fecal Coliform) but also dead animals/plants (Non-Fecal Coliform). If associated with land cover shows that most of the land cover in the upstream area is plantation forest, it can be identified that the source of Total Coliform pollution is human feces (Fecal Coliform).

Table 5. Test results of samples at noon and afternoon times

Parameter	Unit water quality standard class II	Test results		Difference in results
		Afternoon	Evening	
TSS (mg/L)	50	30	24.5	-5.5
BOD (mg/L)	3	0.7	0.95	0.25
COD (mg/L)	25	9	9	0
Total Coliform (MPN/100 mL)	1000 MPN/100 mL	92,000	1,100,000	1,008,000
Fecal Coliform (MPN/100 mL)	5000 MPN/100 mL	92,000	130,000	38.000

3.1.2 Pollution load capacity of Jangkok River, Mataram City

In this study, the analysis of the pollution load capacity of the Jangkok River, Mataram City, was carried out by modeling using QUAL2Kw software. This modeling utilizes water quality monitoring data including Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) parameters collected by the Mataram City Environmental Service (DLH) in October 2022 (Table 6).

Table 6. Results of water quality monitoring of Jangkok River, Mataram City October 2022

No	Parameter	Concentration (mg/L)		
		Upstream	Midstream (Mid. 1)	Downstream
1	TSS	44	378	364
2	BOD	2.62	2.95	3.06
3	COD	86.22	76.57	83.68

(DLH Mataram City, 2022)

The Jangkok River modeling is divided into several segments to allow for more detailed and accurate analysis. This segment division takes into account the physical characteristics of the river, such as changes in width, depth, or flow velocity, as well as the location of the inflow of tributaries or pollution sources. The geographical position of each segment is shown in detail in Table 7, which includes the coordinates of the start and end points of each segment.

Table 7. Geographical position segmentation for modeling Jangkok River, Mataram City

No	Coordinates	Geographical Position		Distance from River Mouth (km)
		LS	BT	
1	Upstream	08°34’22,5”	116°06’32,2”	4.52
3	Middle 1	08°34’28,8”	116°06’09,5”	3.72
4	Middle 2	08°34'33,34"	116° 5'49,15"	3.05
5	Middle 3	08°34'36,09"	116° 5'29,01"	2.39
6	Middle 4	08°34'37,55"	116° 5'11,24"	1.80
7	Middle 5	08°34'29,61"	116° 4'57,83"	1.25
8	Downstream	08°34’23,8”	116°04’42,8”	0.80
9	River Mouth	08°34'26,64"	116° 4'16,85"	0.00

3.1.3 Model Calibration and Validation Results

Calibration is carried out to adjust the water quality value of the monitoring results to be close to the modeling results. It is intended that the model created is close to the actual conditions. Calibration is done using a trial-and-error method, namely changing the concentration value of pollutant sources on the sheet provided. The model calibration results can be seen in Figure 10, Figure 11, and Figure 12.

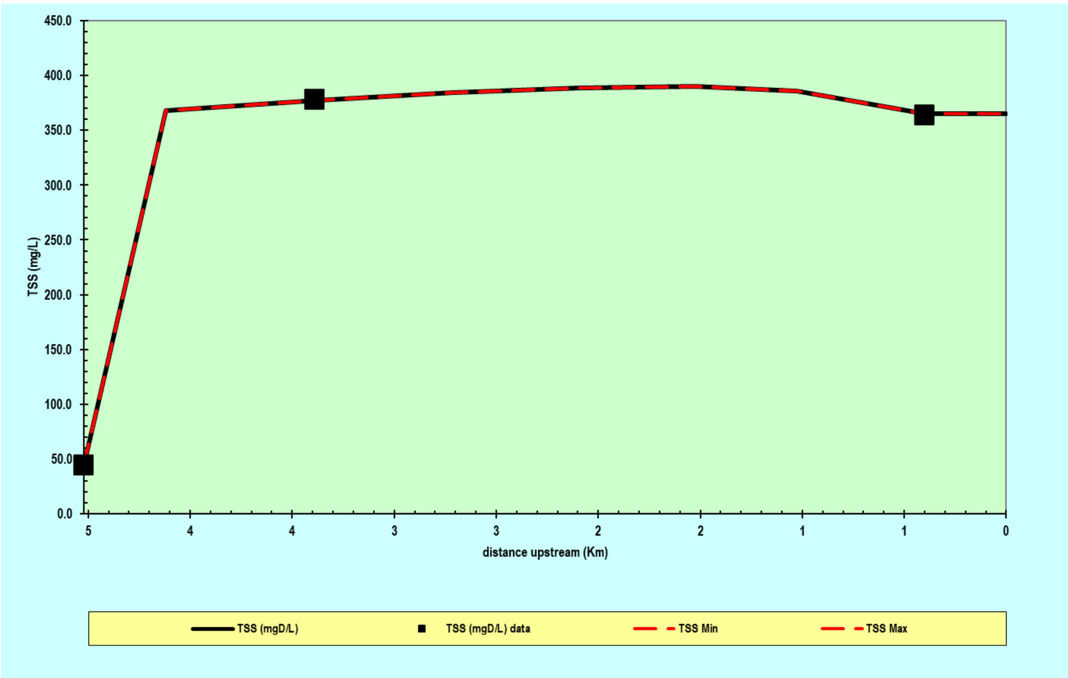
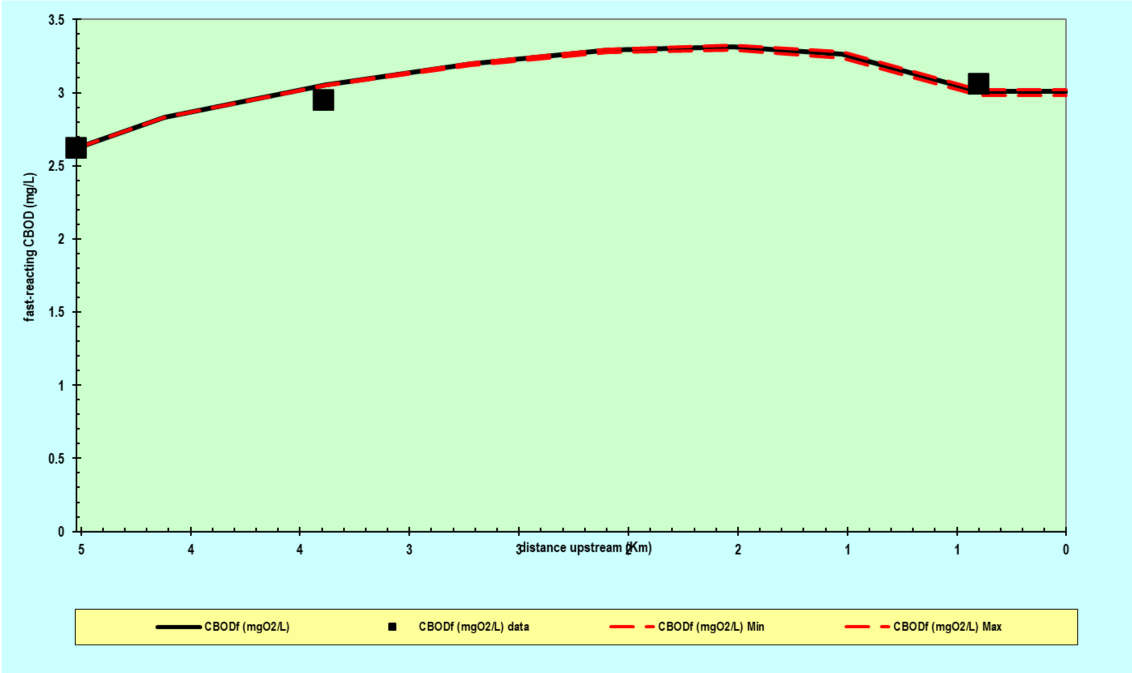
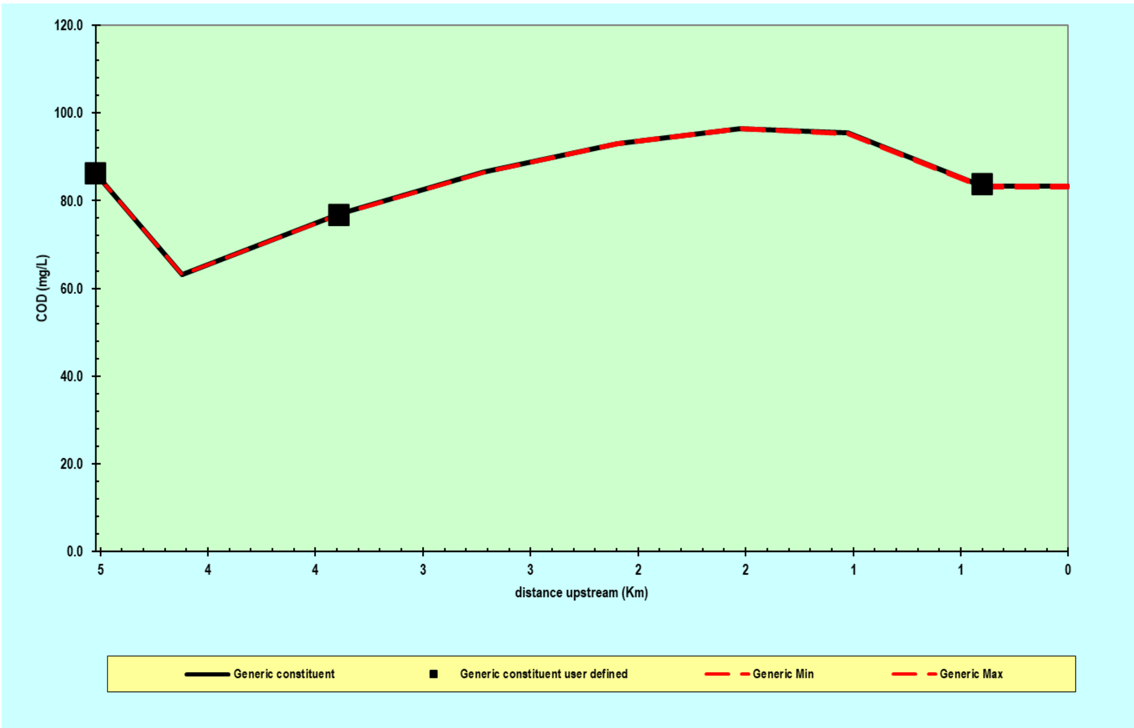


Fig. 10 TSS Model Graph of Jangkok River, Mataram City (3/13/2023)



(a)



(b)

Fig. 11 (a) BOD Model Graph, and (b) COD Model Graph of Jangkok River, Mataram City (3/13/2023)

After calibration, a validation test is carried out to determine whether the resulting model is close to the actual conditions. In this study, validation was carried out by calculating the RMSE value. The model can be good if the RMSE value is ≤1. The results of the calculation of the RMSE value can be seen in Table 8.

Table 8. Results of RMSE Value Calculation

No	Paramete r	Coordinates	Existing Concentration (mg/L)	Model Concentration (mg/L)	RMSE Value
		Upstream	44	44	
1	TSS	Middle 1	378	377.17	0.81
		Downstream	364	364.78	
		Upstream	2.62	2.62	
2	BOD	Middle 1	2.95	3.05	0.08
		Downstream	3.06	3.01	
		Upstream	86.22	86.22	
3	COD	Middle 1	76.57	76.99	0.43
		Downstream	83.68	83,23	

3.2.3 Pollution Load of Simulation Results 1

After it is known that the simulation results model can be considered good, the pollution load entering the Jangkok River, Mataram City, can be calculated. The pollution load is calculated using Equation 3.3 with discharge data and parameter concentrations from the source summary sheet. The results of calculating pollution load based on existing water quality data can be seen in Table 9.

Tabel 9. Results of Pollution Load Calculation from Existing Water Quality

No	Segment	Pollution Load (kg/hari)		
		TSS	BOD	COD
1	Upstream-Middle 1	63980.93	158.63	88.13
2	Middle 1-Middle 2	7133.18	98.15	4990.46
3	Middle 2-Middle 3	7133.18	98.15	4990.46
4	Middle 3-Middle 4	6241.54	85.88	4366.66
5	Middle 4-Middle 5	5795.71	79.75	4054.75
6	Middle 5-Downstream	4904.06	67.48	3430.94

3.2.4 Pollution Load Simulation Results 2

After obtaining pollution load data based on existing water quality, maximum pollution load data is needed to obtain an overview of the pollution load capacity of the Jangkok River, Mataram City. Maximum pollution load data can be obtained from simulation results based on class II water quality standards the government sets. In this second simulation, trial and error are carried out so that the value of the modeling results is close to and does not exceed the Class II water quality standards. Maximum pollution load is calculated using Equation 3.3 with discharge data and parameter concentrations from the source summary sheet. The Maximum Pollution Load Calculation results can be seen in Table 10.

Table 10. Maximum pollution load calculation results

No	Segment	Pollution Load (kg/days)		
		TSS	BOD	COD
1	Upstream-Middle 1	1894.75	96.94	660.96
2	Middle 1-Middle 2	829.44	78.80	1105.92
3	Middle 2-Middle 3	829.44	78.80	1105.92
4	Middle 3-Middle 4	725.76	68.95	967.68
5	Middle 4-Middle 5	673.92	64.02	898.56
6	Middle 5-Downstream	570.24	54.17	760.32

3.2.5 Condition of Pollution Load Capacity

The condition of the pollution load capacity of the Jangkok River, Mataram City, can be determined by reducing the maximum pollution load with the existing pollution load. The results of the reduction can be seen in Table 11. Based on this table, it can be seen that the incoming BOD, COD and TSS pollution loads have generally exceeded the pollution load capacity of the Jangkok River, Mataram City. Only the COD parameter in the Upstream-Middle 1 segment does not exceed the pollution load capacity. In this segment, there was a decrease in the concentration of the COD parameter from 86.22 mg/L to 76.57 mg/L. This shows that the self-purification process is running well in the segment. The high pollution load in other segments and parameters occurs due to the dense population settlements that produce domestic waste in garbage and liquid waste. For TSS, a significant increase in pollution load occurred upstream. This is likely due to high sedimentation caused by landslides, soil erosion, and domestic waste disposal.

Tabel 11. Maximum Pollution Load Reduction Results with Existing

No	Segment	Pollution Load Reduction Result (kg/days)		
		TSS	BOD	COD
1	Upstream-Middle 1	-62086.10	-61.69	572.83
2	Middle 1-Middle 2	-6303.74	-19.35	-3884.544
3	Middle 2-Middle 3	-6303.74	-19.35	-3884.544
4	Middle 3-Middle 4	-5515.78	-16.93	-3398.976
5	Middle 4-Middle 5	-5121.78	-15.73	-3156.192
6	Middle 5-Downstream	-4333.82	-13.31	-2670.624

3.2 Discussion

Environmental issues are complex because they involve interactions between humans and other living things and their environment. To deal with these problems, interdisciplinary studies are needed. Not only to maintain the quality of inanimate objects (water, air and energy) but also to maintain the sustainability of human life socially and economically. When handling environmental problems, one must think about the future and the long term. River water pollution is one of the environmental problems that occur in Jangkok River, Mataram City. The water quality status of the Jangkok River, Mataram City, based on the STORET method, shows most of the heavy pollution that occurred from 2015-2022. The parameters TSS, BOD, COD, *E. coli* and Total Coliform are the parameters whose values most consistently exceed class II water quality standards.

There are two previous studies related to water pollution in Jangkok River, Mataram City, namely: 1) Idrus (2015), which showed that the river was polluted in 2014 based on direct physical, chemical and biological testing; and 2) Diantari et al., (2017), which showed that the river was heavily polluted with organic matter in the middle and downstream parts in 2016 based on the Family Biotic Index (FBI) value. The research conducted by Idrus (2015) did not conclude that the river was heavily polluted and where the pollution area occurred. The study was based on physical properties (pungent odour, very turbid water colour, high temperature), chemical properties (PH<5, the presence of clots after the sample was mixed with tea), and biological properties (the presence of moss contaminating the water). In research conducted by Diantari et al. (2017), it was concluded that heavy pollution did not occur upstream because the FBI value was 4.6, which was categorized as good.

This result differs from the author's analysis, which shows that all parts of the river were heavily polluted in 2016. This difference occurs because the analysis of water quality status using the STORET method uses water quality data for one year (4 monitoring times). Let us look at the water quality data of the Jangkok River, Mataram City, in 2016. We can see that the organic pollution indicator (BOD) has a concentration that exceeds class II water quality standards in March and May, while in September and November, it does not exceed class II water quality standards. Based on this, it can be shown that macro results in different water quality statuses, but micro, if using 1-time monitoring, will produce the same water quality status. Differences in concentrations that exceed water quality standards can be caused by seasonal differences, namely dry and rainy seasons. The sampling conducted by

Diantari et al. (2017) was most likely done during the rainy season. This difference in results provides input to the author so that the next analysis of water quality status can distinguish the results based on seasonal differences.

River water pollution becomes a complex problem if the incoming pollution load exceeds capacity. This happens because there needs to be an effort to reduce the pollution load so that it does not exceed its capacity. Based on the results of the QUAL2Kw simulation, the parameters BOD, COD and TSS in all parts of the Jangkok River, Mataram City, in 2022 have mostly exceeded the pollution load capacity according to class II water quality standards. This shows that river water quality affects the capacity of the pollution load of the Jangkok River, Mataram City. When comparing the BOD pollution load produced by the author with the results of research conducted by Marganingrum et al. (2018), the BOD pollution load has decreased by about 96% from 2016 to 2022. Based on these two comparisons, it can be concluded that pollution reduction has been quite successful in the upstream part of the Jangkok River, Mataram City. According to the author, pollution reduction is also successful in the middle and lower reaches of the Jangkok River, Mataram City. This is supported by data on improving water quality in all parts of the river. Because BOD, COD, and TSS can be sourced from domestic waste, community behavior, waste disposal systems, and waste management in settlements are the most critical improvement aspects.

4. Conclusions

In general, Jangkok River, Mataram City, is in a heavily polluted category from 2015 to 2022 with an average STORET score of -79.25, and the pollution load of BOD, COD and TSS parameters has exceeded the capacity of the pollution load. The condition of the Jangkok River, Mataram City, which is heavily polluted, is influenced by people's behavior of defecating and throwing garbage in water bodies (23%), as well as poor prevention behavior (59%), poor wastewater disposal facilities (40%) and garbage (58%) and the number of houses with their backs to the river (59%). The involvement of government agencies and NGOs is hampered by the lack of synergy between institutions across districts/cities, poor law enforcement to the community, no disincentives for managers, and work programs that are highly dependent on government budgets. The appropriate strategy for sustainable control of water pollution in the Jangkok River, Mataram City is to create a pollution load reduction program that is integrated across districts/cities, integrated across institutions with different authorities, integrated with the community, and in accordance with the actual conditions of the river and the socio-economics of the community.

Acknowledgement

The authors would like to thank the NTB Provincial Environmental and Forestry Service, the Mataram City Environmental Service and other agencies/institutions as well as the local community who have provided a lot of assistance in obtaining the data the author needed.

Author Contribution

Conceptualization, I.H., H.A., & T.E.B.S.; Methodology, , I.H., H.A., & T.E.B.S.; Software, , I.H., H.A., & T.E.B.S.; Validation, , I.H., H.A., & T.E.B.S.; Formal Analysis, , I.H.; Investigations, , I.H., H.A., & T.E.B.S.; Resources, , I.H., H.A., & T.E.B.S.; Data Curation, , I.H.; Writing – Original Draft Preparation, , I.H.; Writing – Review & Editing, I.H.; Visualization, I.H.

Funding

This research received no external funding.

Ethical Review Board Statement

Not applicable.

Informed Consent Statement

Not available.

Data Availability Statement

Not availbale.

Conflicts of Interest

The authors declare no conflict of interest.

Open Access

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