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*Regional Case Study*

# Pollution Index Analysis and Water Pollution Control Strategy in Berenyok River, Tanjung Karang, Mataram City

**M Said Ramdlan[1], Uzlifatul Azmiyati[1]***
[1] Environmental Engineering Department, Engineering Faculty, Universitas Nahdlatul Ulama Nusa Tenggara Barat, Jl. Pendidikan No. 6 Mataram, NTB, Indonesia
*Corresponding Author, email: u.azmiyati@gmail.com

## Abstract

Berenyok river is one of the water sources in Tanjung Karang, Mataram city, categorised as Class 2 for its designation. Thus, preserving the quality of water in the Berenyok river is crucial. This study aims to determine the water quality, calculate the Pollution Index (PI), and set control strategies for the Berenyok river. The study uses quantitative methods such as laboratory analysis for the water quality and PI calculation using a formula based on the Decree of the Minister of Environment No.115/2003 on determining water quality status. Meanwhile, the Strengths, Weakness, Opportunities, and Threats (SWOT) analysis generates recommendations for water pollution control strategies. The sampling locations are located in two sampling points (upstream and downstream of the Berenyok river) during bright daylight and the river's normal flow. Based on analysis results, the Berenyok river is defined as lightly polluted as the concentrations of several chemical parameters exceed the maximum limit, such as BOD, and $PO_3$-P. It is also verified by high concentration of total coliform, namely 540,000 MPN/100mL (upstream) and 1,600,000 MPN/100mL (downstream). Thus, recommendations for water pollution control strategies are substantial for the Berenyok river.

**Keywords**: Water quality; pollution index; control strategies; berenyok river

## 1. Introduction

Population growth is increasing each year significantly in Mataram city. According to BPS-Statistics Mataram, in 2020, the number of populations in Mataram city is growing by 4%, compared to that in 2017. The growth is relatively high due to the Mataram area being only 61,30 km$^2$. The increasing population number means higher demands from society. One of them is water hygiene. The community commonly uses water hygiene to comply with their daily needs, such as sanitation, recreation, irrigation, livestock, and agriculture. These high activities may adversely affect the environment. The wastes produced from the activities are inevitable and may worsen the water quality in the river (Mahyudin et al., 2015).

Degradation of water quality directly affects the environment and society. The low water quality can influence the background as the habitats for aquatic biota in that area. For example, high water turbidity may disturb the photosynthesis process, lowering the oxygen required by the marine biota. Furthermore, water, which has relatively long cycles, is crucial for humans. As the water is contaminated, human tends to be infected by various waterborne diseases, which can also cause death (Fazal-ur-Rehman, 2019).

Berenyok river is one of four rivers in Mataram city. The river flows through the Tanjung Karang areas, which are administratively located in the Sekarbela sub-district, Mataram city. Tanjung Karang is an urban area which is the second most populated area in the Sekarbela sub-district (BPS, 2021). Berenyok river is 48 km in length and has a large of 2.277,5 Ha. This river is used for natural drainage, irrigation, and surface water which fulfil the needs of society (RPJMD Kota Mataram, 2021). The adequate inflow of the Berenyok river is within 15 million m3/year, approximately 0.48 m3/s (Balai Wilayah Sungai Nusa Tenggara 1, 2021). As the Berenyok river flows nearby community settlements, the river is not only used as a water hygiene source but also as a domestic water discharge area. This condition triggers to lowering water quality of the Berenyok river.

Decreasing water quality was observed by analysing some parameters, such as physical, chemical, and biological parameters (Djoharam et al., 2018). The analysis results are then compared to prevailing national water quality standards, which comply with the water classification in the 6th attachment of government regulation No. 22 of 2021 on environmental protection and management. The values obtained from the analysis results and government regulations are used to calculate water pollution levels by pollution index methods by Ministerial of Environment Decree No. 115 of 2003 on determination guidelines of water quality status. The pollution index (PI) is a simple and easy measure of water pollution levels. This method produces a value indicating the relative pollution against the water quality standards. In recent years, some studies have been carried out to determine river water quality using the Pollution Index method (Nurrohman et al., 2019; Suriadikusumah et al., 2021; Widodo et al., 2019). Based on the elaborated problems above, the aims of the study are to (1) analyse the quality of water in Berenyok river, Tanjung Karang, Mataram city, (2) calculate the water pollution index and (3) formulate a water pollution control strategy for Berenyok river. Hence, it is urgent to research to maintain the sustainability of water hygiene for the society of Tanjung Karang, Mataram city.

## 2. Methods

The study was conducted in Berenyok river, Tanjung Karang, Mataram city, using a quantitative approach. The study to determine the water quality was plotted in two locations in the river body, mainly upstream and downstream. The locations were chosen as the sampling locations using purposive sampling methods based on the accessibility, cost, and time of the study. The water sampling method was directly taken using the grab sampling method upstream and downstream, based on the administrative boundaries of Tanjung Karang, Mataram city. The locations were chosen to measure the river's water quality within the areas of Tanjung Karang. This sampling method was determined as the study was conducted in bright daylight and regular flow of the river, which can represent waste composition or water body (Ramadhani et al., 2020). The primary data, such as water samples, observations and key-informant interviews, were taken in March 2022 (dry season). Meanwhile, secondary data were also obtained from literature, BPS, etc. The location of the study is depicted and can be seen in Figure 1.

Some parameters are analysed, such as physical, chemical and microbiological parameters in the Environmental Laboratory of Dinas Lingkungan Hidup dan Kehutanan (DLHK) West Nusa Tenggara Province. The assessment of water quality is determined based on Class 2 for water classification in the 6th attachment of government regulation No. 22 of 2021 on environmental protection and management. Whilst, based on Decree of the Minister of Environment No.115/2003, the determination of water quality status is calculated using PI method using formula (1)

$$PI_j = \sqrt{\frac{(C_i/L_{ij})_M^2 + (\frac{C_i}{L_{ij}})_R^2}{2}} \tag{1}$$

Where:

PIj = Pollution index for the designation (j)

Ci = Concentration of water quality parameters from survey results

Lij = Concentration of water quality parameters stated in the water quality standard (j)

$(Ci/Lij)_M$ = Maximum value Ci/Lij

$(Ci/Lij)_R$ = Average value Ci/Lij

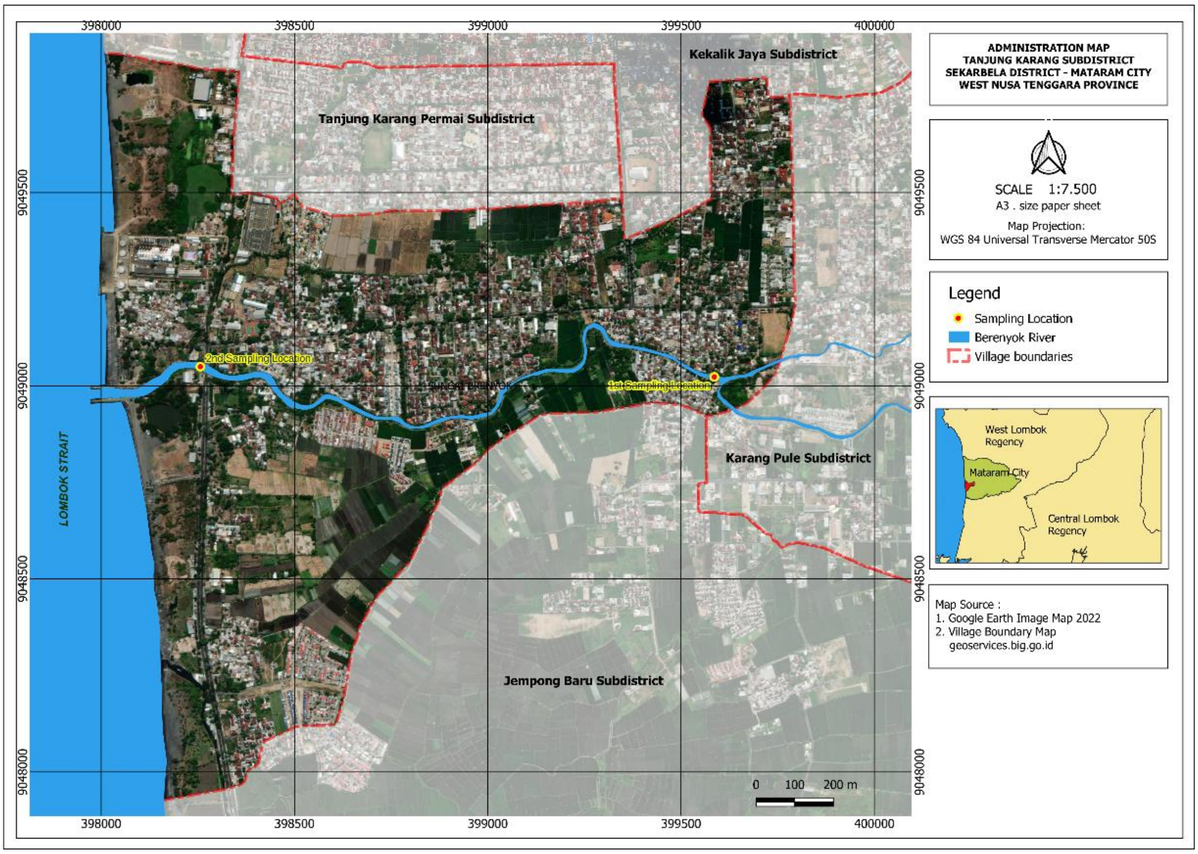



**Figure 1.** Study area

For each parameter, single measurements in the laboratory were conducted for each water sample. To examine the quality control of analysis, precision control (Duplo) was calculated to determine the acceptance criteria or relative per cent difference (%RPD), namely below 30%. It was found that % the RPD of all parameters was within acceptable values. Physical parameters were analyzed, such as temperature, Total Dissolved Solids (TDS), and Total Suspended Solids (TSS). Temperature and TDS were measured in the sampling locations. The temperature was measured in Celsius degree ($^oC$) using a thermometer, while TDS was determined using portable electrometry, expressed in mg/L. TSS was quantified by gravimetric analysis. Water samples were homogenized and sieved using a micro glass -fibre filter with a pore diameter of 0.7 – 1,5 µm. Residues were subsequently dried at the temperature of 103$^o$C – 105$^o$C. The weight differences between the pre-weighed micro glass-fibre filter and dried samples-weighed micro glass-fibre represented the TSS concentration in mg/L.

Chemical parameters consisted of pH, Biochemical Oxygen Dissolved (BOD), phosphate ($PO_3$-P), nitrate ($NO_3$-N), and Dissolved Oxygen (DO). pH values were measured in the laboratory along with other parameters using a pH meter. BOD concentrations were calculated five days after incubation at a temperature of 200C ± 10C in the dark. Furthermore, the Micro 800 optical DO meter – Palintest was used to determine the concentration of DO in each location. Meanwhile, for $PO_3$-P engagement, solutions such as orthophosphate in acidic solution were reacted with Ammonium molybdate, and antimony potassium tartrate and solution concentrations were measured in spectrophotometer UV-Vis at the wavelength of 880 nm. In a similar principle, $NO_3$-N was analyzed using portable photometry (Hanna instrument HI83399) at 525 nm.

As supporting data, Total coliform was tested to determine biological activities in the river body. Water samples were filtered via a membrane filter to retain organisms, and membrane filter was placed on a chromogenic agar plate. The membrane filter was then incubated at 36 ± 2 $^{o}$C for 21 ± 3 hours. Total coliform bacteria were the sum of oxidase-negative colonies with pink to read colour and all dark-blue to violet colonies. The water pollution control strategy for the Berenyok river is arranged based on the result of water quality analysis and Pollution Index (PI) using SWOT analysis. In SWOT analysis, it is determined the Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T) for the pollution control strategy of the Berenyok river. In addition, the recommendations for water pollution control strategies are set to optimally support the Strengths and Opportunities while simultaneously eradicating or minimising the Weaknesses and threats (Rangkuti, 2013).

## 3. Result and Discussion

### 3.1. Water Quality of Berenyok River

Water is considered polluted if some parameters (physical, chemical and microbiological) exceed the maximum limit of the quality standards by the water classification in the 6th attachment of government regulation (GR) No. 22 of 2021 on environmental protection and management. As Berenyok river is categorised as Class 2 for water quality standards, the parameters analysed in this study were compared with Class 2 water quality standards. Physical parameters are used to identify water quality initially. Temperature, as one of the physical parameters, determines the ecosystem of the watershed (biotic and abiotic components). The typical temperature for a water body in tropical countries is around 25 – 30 $^{o}$C. At low and high temperatures, aquatic biotas and plants are disrupted as DO content decreases (Dahruji et al., 2016). According to the analysis, the temperature in both sampling locations (upstream and downstream) is average, namely 27 $^{o}$C.

TDS is a term used for expressing the amounts of dissolved substances (anions and cations) in the solution. TDS values upstream and downstream of Berenyok river are below the maximum limit of water quality standards for Class 2 in GR No.22/2021, which is 123 mg/L and 140 mg/L, respectively. TDS is closely related to conductivity. The higher the TDS value, the higher conductivity of water (Nicola, 2015; Tebbutt, 1992). It can be seen that conductivity downstream (280 µS/cm) is slightly higher than upstream (245 µS/cm). It is most likely because the sampling location downstream is close to the seawater estuary. Yet, both conductivity values in the study area are still suitable for irrigation (Fitriyah, 2012).

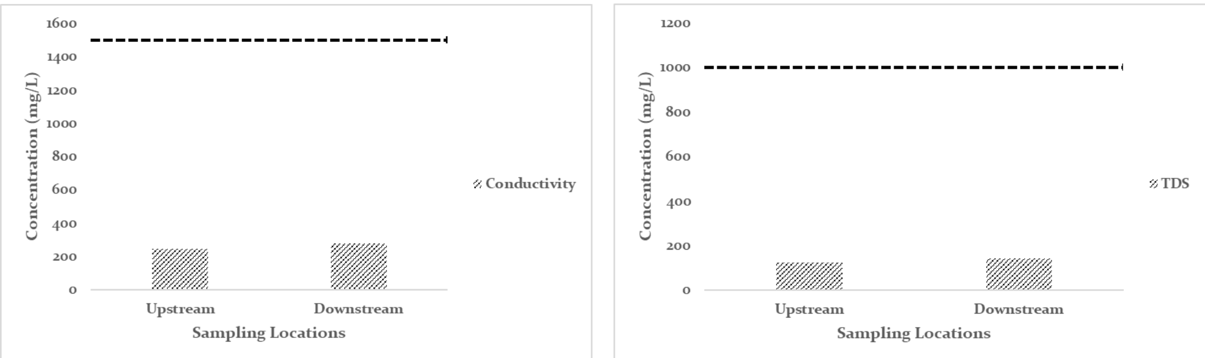


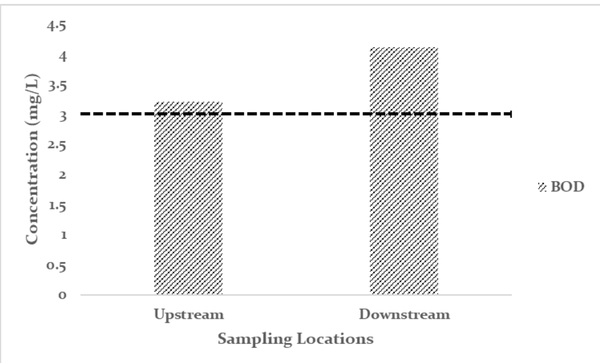

**Figure 1.** TDS and conductivity concentration in Berenyok river

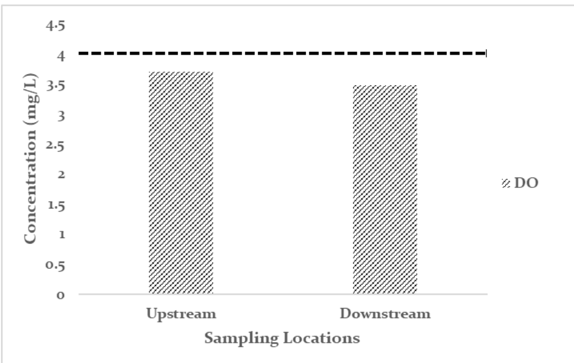
TSS shows the amounts of inorganic matters such as sludges, clays, metal oxides which have more than 2 microns in size and organic issues, and microorganism cells (Nasution, 2008). TSS value can be used to assess the turbidity level of the watershed (Rügner et al., 2013). Upstream, TSS concentration nearly reaches the threshold (50 mg/L). High TSS concentration depicts more inorganic matters in this sampling area than downstream, 15 mg/L. It is most likely due to particles contributing to TSS accumulated and precipitating downstream as the river flows toward the downstream areas (Adnyana et al., 2017). Hartini et al., (2015) turbidity level in Berenyok river ranges from 6.78 – 8.9 NTU.

In terms of chemical parameters, pH value is a crucial parameter to monitor water stability as it can determine the habitat condition of the aquatic microorganisms. Most aquatic biotas prefer a pH of 6 – 9, and higher pH could lead to higher mortality of the organisms (Supriatna et al., 2020). Since the Berenyok river has pH values of 6.65 and 6.67 for upstream and downstream, respectively, pH values in this study still comply with the quality standards. Similarly, the concentration of Nitrate-N ($NO_3$-N) upstream and downstream of the Berenyok river is still below the maximum limit of Class 2 water quality standard (10mg/L), namely 0.63 mg/L and 1.51 mg/L. the concentration of $NO_3$-N in the river body can be used as a pollution indicator due to its high availability. Generally, nitrate concentration originates from agricultural activities such as using chemical fertilizers – urea and ZA (Amalia et al., 2021). In optimum concentration, nitrate is beneficial for aquatic-plant growth, yet higher concentration may cause eutrophication, affecting DO and temperature (Khan and Mohammad, 2014).

In contrast, Phosphate-P ($PO_3$-P) content appears to have a higher value upstream and downstream. $PO_3$-P content in the river can be derived from agricultural, industrial, and domestic activities (Colborne et al., 2019; Smith et al., 2006). $PO_3$-P concentration can also indicate eutrophication in the water body (Smith et al., 2006). According to the regulation, $PO_3$-P content, which is permitted, is around 0.2 mg/L for Class 2. However, $PO_3$-P content in the Berenyok river seems to exceed the maximum limit, namely 0.45 mg/L (upstream) and 0.51 mg/L (downstream). High concentrations of $PO_3$-P in this area are most likely due to the residential activities along the river, such as washing and detergent use from households (Kundu et al., 2015).

BOD presents the amount of DO required by microorganisms to decompose organic matters in aerobic conditions (Tanjung and Hamuna, 2019). Microorganisms need this oxygen content for respiration to oxidize organic compounds like $NH_3$, $NO_3$, cellulose, lignin and others. A high concentration of BOD may also specify an increased number of microorganisms in water. As a result, DO content in the watershed is dropped as oxygen is consumed. In addition, a high BOD concentration may result in foul odours as the DO content decreases, leading to the degradation of organic matter in water bodies within anaerobic conditions. The reaction during this circumstance produces methane gas from this degradation process (Susilowati, 2011). Upstream and downstream of the Berenyok river, BOD concentrations exceed the permittable limit (3 mg/L), which are 3.2 mg/L and 4.1 mg/L, respectively. This condition is likely caused by organic wastes from domestic areas surrounding the location as a result of several activities such as livestock, washing, and detergent use (Widodo et al., 2019).



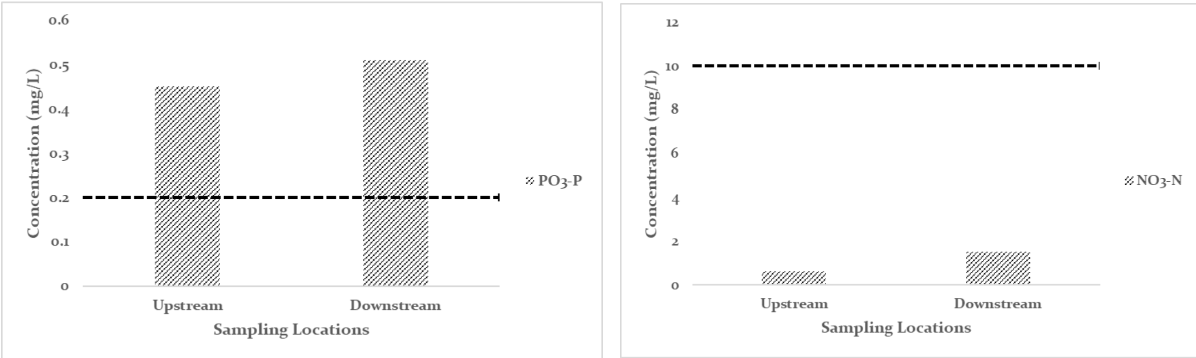



**Figure 2.** Concentrations of $PO_3$-P, $NO_3$-N, BOD and DO in upstream and downstream compared with class 2 water quality standards

Total coliform consists of two groups which are faecal and non-faecal coliform. The common faecal coliform is E. Coli, derived from human faeces, while non-faecal coliform, Aerobacter, is from dead animals and plants (Pakpahan et al., 2015). According to Rompas et al. (2019), total coliform is widely used as the indicator of pollution in a water body, measured in the most probable number per 100 mL (MPL/100mL). The permittable concentration for total coliform is 5000 MPN/100mL. Based on the analysis, total coliform concentrations upstream and downstream in the Berenyok river are high, 540,000 MPN/100mL and 1,600,000 MPN/100mL, respectively. High concentrations of total coliform found in the locations were similar to total coliform in the Plumbon river (Pratiwi et al., 2019). Populated settlements and the closed distance of the houses may cause the pollution of the watershed by coliform bacteria (Fathoni et al., 2016). The White – sanitation book of Mataram city in 2010 by the working groups of AMPL (drinking water and environmental sanitation) stated that the high concentration of total coliform in a watershed is due to animal faeces, dead plants and animals, domestic wastes from the communities. According to Pelczar and Chan (1988), the growth of coliform bacteria does not depend on the concentration of dissolved oxygen; this is mainly because these bacteria are facultative-anaerobic bacteria which can live with or without oxygen.

### 3.2. Pollution Index (PI)

Based on the laboratory analysis of the water quality from upstream and downstream in the Berenyok river, some parameters exceeded the standards for Class 2, namely BOD, DO, $PO_3$-P, and Total Coliform. In general, organic matter contents in the study area induces pollution to occur. Meanwhile, other parameters still comply with government regulation, except for TSS upstream. The values of physical and chemical parameters were used to calculate the PI in the study area. The PI assessment was conducted using the formula stated in the Decree of the Minister of Environment No.115/2003 on water quality status. PI upstream and downstream in the Berenyok river are portrayed in Table 1.

**Table 1.** The relationship of PI with water quality status

| No | Sampling Locations | PI Values | Water Quality Standards |
|---|---|---|---|
| 1 | Upstream | 2.04 | Lightly polluted |
| 2 | Downstream | 2.23 | Lightly polluted |

As stated in Table 1 above, both locations are lightly polluted based on the regulation. The PI value downstream is slightly higher compared to that upstream. It is likely due to most parameter concentrations, physical and chemical, higher downstream resulted in a higher value for PI. Hartini et al. (2015) Family Biotic Index of the Berenyok river is around 7.1 – 8, with an average value of 7.75 representing poor water quality. This condition is also supported by the total coliform concentration in the downstream area is exceptionally high. These PI values are lower than other PI values of other rivers in Indonesia (Suriadikusumah et al., 2021; Widodo et al., 2019). However, particular controlling strategies are still required to minimise further impacts of pollution in the watershed.

### 3.3. Pollution Control Strategies

The strategies for controlling the pollution in Berenyok river were arranged based on the water quality analysis, literature study, observation, and key–informant interviews with society and local government. Key-informant interviews showed that the water quality of the Berenyok river experienced a degradation process from time to time. Some observable changes that can be seen are turbid river water and increasing waste volume in the watershed. Farizal, a neighbourhood head of Batu Ringgit in Tanjung Karang, stated that river water is cloudy and more wastes are thrown away by the society into the river.

Based on prior laboratory results, observation, literature study and key-informant interviews, it is crucial to set recommendations for controlling pollution strategies considering the related internal and external factors. Considering these two factors can result in defining the study area's strengths, weaknesses, threats, and opportunities (Ermawati et al., 2019). Internal factors comprise the strengths and weaknesses, whereas external factors are opportunities and threats. The control strategy for pollution in the Berenyok river is clearly described in Table 2.

**Table 2.** Pollution control strategies for Berenyok river

| No | Internal Factors | |
|---|---|---|
| | **Strengths** | **Weakness** |
| 1 | The presence of wastewater standards discharged to surface water sources | In general, water quality of Berenyok river is not complied with Class 2 standards. |
| 2 | The presence of local government on pollution control and environmental damage | Berenyok river is lightly polluted |
| 3 | The communities in Tanjung Karang have knowledge on pollution source in Berenyok river. | the awareness of Tanjung Karang society is low on waste water management and treatment. |
| 4 | - | Not determining the pollution load carrying capacity of Berenyok river |
| 5 | - | No inventory and identification of pollution sources in Berenyok river |
| | **External Factors** | |
| | **Opportunities** | **Threats** |
| 1 | The existence of environmental care communities in Mataram City | The majority of households disposing their domestic waste to water body in Berenyok river |
| 2 | The high advancement of technology for domestic waste management | Few people from communities still use Berenyok river as waste dumping areas |
| 3 | Local government supports | Water quality status of Berenyok river is prone to heavily polluted |
| | **Strategies** | |
| | **Strengths – Opportunities** | **Weakness – Opportunities** |
| 1 | The use of technology to manage domestic wastes in Tanjung Karang | Starting to change community habits such as minimize the amounts of domestic wastes and manage/treat domestic wastes before discharging to Berenyok river |
| 2 | Environmental care community to educate the society to preserve the environment | The collaboration from society with government to define the carrying capacity of the pollution load in Berenyok river |
| 3 | Society and government cooperate to support the facilities and infrastructures for public | Society and government work together to make an inventory and identification of |

| | | |
|---|---|---|
| | wastes and domestic waste treatment in Tanjung Karang | pollution sources in Berenyok river |
| | **Strengths – Threats** | |
| 1 | Environmental care community preserves and monitors protection zones alongside the river; supervision on controlling pollutions of Berenyok river | |
| 2 | Increase monitoring of water quality and supervision on wastes and wastewater discharges to the Berenyok river | |

These strategies can be one of the priorities to control the water pollution in Berenyok river, Tanjung Karang. Collaborations of stakeholders, like the environmental care community, society, and government, are required to execute the strategies to continuously and sustainably run.

## 4. Conclusions

The parameters analysed in this study for the Berenyok river were pH, temperature, TDS, TSS, DO, BOD, $PO_3$-P, $NO_3$-N, and total coliform. Specific parameters, such as BOD, DO, and $PO_3$-P, exceed the water quality standards for Class 2 in the Berenyok river in both streams (upstream and downstream), respectively 3.2 mg/L and 4.1 mg/L, 3.7 mg/L and 3.47 mg/L, 0.45 mg/L and 0.51 mg/L. In addition, this study's noticeable total coliform values are 540,000 MPN/100mL (upstream) and 1,600,000 MPN/100mL (downstream), which are incredibly high compared to the standards of 5,000 MPN/100mL. The assessment of the Pollution Index based on the concentration of physical and chemical parameters for Class 2 water standards was conducted using a formula by Decree of the Minister of Environment No.115/2003 on the determination of water quality status. The calculation concludes that the Berenyok river is lightly polluted. Based on SWOT analysis, some recommendations to control pollution strategies in Berenyok river are preserving the protection zones alongside the river, educating the society to protect the environment and monitoring, supervising and controlling the pollution in collaboration with the environmental care community, culture and local government.

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