Water quality analysis during tidal conditions using the Pollution Index Method in the Karang Mumus River, East Kalimantan

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ABSTRACT

The Karang Mumus River, located in East Kalimantan, serves as an essential resource for the local community, supporting fisheries, trade, and household activities. However, these uses contribute to waste accumulation, potentially impacting the river's water quality. Tidal movements play a crucial role in water circulation, with the river's flow influenced by the Mahakam River's tides, leading to backwater flow during high tide. This tidal phase affects the dispersion of pollutants. This study aims to assess the water quality, Pollution Index, and variations in water conditions between high and low tide in the Karang Mumus River. Sampling was conducted at three research stations: Station 1 (Gelatik Bridge), Station 2 (Perniagaan Bridge), and Station 3 (Selili Bridge) from September to November 2023. Water quality measurements were performed both in situ (on-site) and ex situ (at the Water Quality Laboratory, Faculty of Fisheries and Marine Science, Mulawarman University). The analysis follows Government Regulation (PP) No. 22 of 2021 on Environmental Protection and Management (Appendix VI). Results indicate that the DO and COD parameters only meet class III-IV water quality standards, while color, temperature, TDS, TSS, BOD, total phosphate, and nitrate comply with class I-IV standards. The Pollution Index (IP) assessment, based on class I-IV quality standards, categorizes the Karang Mumus River as meeting quality standards to lightly polluted, with an IP range of 0.53 - 2.90. According to Minister of Environment Decree No. 115 of 2003, water meeting quality standards has an IP of 0 < IP < 1.0, while lightly polluted water falls within 1 < IP < 5.

INTRODUCTION

Rivers play an essential role in supporting life. They serve as habitats for aquatic biota and are utilized by humans for various purposes. The Karang Mumus River is a tributary of the Mahakam River. However, as a vital resource for communities along its watershed, the Karang Mumus River has experienced a decline in water quality. This deterioration is marked by black-colored water, foul odors from decomposing waste, and the accumulation of floating garbage on the water's surface (Daramusseng & Syamsir, 2021).

The condition of a river is closely related to human activities along its banks. Poor river conditions are often caused by dense residential settlements and social activities along the riverbanks. Many people use the river for bathing, washing, and sanitation (MCK), even though the water quality is unsuitable for such purposes (Wijaya et al., 2017). Several factors influence river water quality, including the discharge of domestic waste and the presence of open defecation (Widiyanto et al., 2015). Additionally, water quality directly affects the ecosystem of aquatic organisms. Natural factors, such as tidal fluctuations, also influence river water quality (Siregar, 2004).

Tides are the primary driving force behind water circulation. During high tide, water from the larger upstream watershed increases the water volume in the river estuary, and the opposite occurs during low tide. The flow of the Karang Mumus River is affected by the tides of the Mahakam River, causing a backwater effect during high tide (Pramaningsih et al., 2020). Tidal phases influence the distribution patterns of pollutants within the river (Fan et al., 2009).

The Pollution Index (IP) is one of the methods used to determine the level of river water pollution. This method involves a relative calculation comparing observed water quality parameters to established quality standards. As a composite index, the Pollution Index consists of an average index and a maximum index. Considering these factors, this study aims to analyze water quality using the Pollution Index method in the Karang Mumus River. The research seeks to determine the extent of pollution in the river and provide insights into its current environmental condition.

METHODOLOGY

The study was conducted from September to November 2023 at the Karang Mumus River. Water quality parameter analysis was carried out at the Water Quality Laboratory, Faculty of Fisheries and Marine Science, Mulawarman University.

The research followed several stages, including preparation (literature review), determination of sampling stations, measurement of water quality parameters and laboratory testing, data processing, and final report preparation.

Water sample analysis was conducted using both in situ and ex situ methods. The in situ analysis involved direct measurements in the field during sample collection, while the ex situ analysis involved collecting water samples for further examination at the Water Quality Laboratory of the Faculty of Fisheries and Marine Science, Mulawarman University.

The pollution index analysis in this study was carried out using a descriptive approach to determine the relative level of pollution based on water quality parameters. The assessment adhered to the Decree of the Minister of Environment No. 115 of 2003 and Government Regulation No. 22 of 2021, Annex VI on water quality standards.

RESULT AND DISCUSSION

Color

Water has two types of color: true color, which is caused solely by dissolved chemical substances, and apparent color, which is influenced not only by dissolved substances but also by suspended materials (Melinda & Oka, 2020). The color values at the observation stations ranged from 36.094 Pt-Co to 59 Pt-Co. The highest value was recorded at Station 1 during low tide at 59 Pt-Co, while the lowest was at Station 3 with 36.094 Pt-Co. The color parameter at Stations 3 and 2 is within safe limits for water quality standards of Classes I–IV, whereas Station 1 meets the safe limit for Classes II–IV. The water color in the Karang Mumus River is affected by household waste, market waste, and industrial waste containing chemicals, human waste from public sanitation facilities, soap, oil, and organic/inorganic trash, making the water turbid and odorous. This aligns with the study by Daramusseng & Syamsir (2021) on the Karang Mumus River.

Temperature

Water temperature is influenced by seasons, cloud conditions, air-water interaction processes, geographical location, and wind gusts (Dahuri et al., 2006). Temperature changes affect physical, chemical, and biological processes in a water body and play a role in controlling the aquatic ecosystem (Hamuna et al., 2018).

The water temperature was lower during high tide than during low tide. The lowest temperature during high tide was 27.6°C at Station 2, while the highest temperature during low tide was 29.8°C. The temperature range of the Karang Mumus River, in both tidal conditions, is suitable for supporting aquatic life, consistent with the findings of Mariani et al. (2021). According to Government Regulation No. 22 of 2021, the standard water temperature deviation for river water quality Classes I–IV is 3°C (24–30°C).

Total Dissolved Solids (TDS)

Dissolved solids are smaller in size than suspended solids. TDS represents the total amount of dissolved materials that can pass through a filter smaller than 2 µm (Pingki, 2021). The TDS levels in the Karang Mumus River at the three stations meet the water quality standards for Classes I–IV. The highest TDS value was recorded at Station 1 during low tide at 233.8 mg/L, while the lowest was at Station 3 during high tide at 73.2 mg/L. The high TDS value at Station 1 is attributed to pollution from industrial waste and public sanitation facilities. According to Hidayat et al. (2016), TDS values in water bodies are significantly influenced by rock weathering, surface runoff, and anthropogenic factors (such as domestic and industrial waste).

Total Suspended Solids (TSS)

Suspended solids in water can include plankton, microbes, human and animal waste, decomposed plant or animal matter, and industrial waste (Soewandita & Sudiana, 2010). Suspended solids can reduce sunlight penetration into the water, affecting photosynthesis and reducing oxygen availability (Hendrawan et al., 2016).

TSS levels across the three stations during high and low tide ranged from 10.3 mg/L to 39.7 mg/L. The highest TSS value was recorded at Station 1 during low tide (39.7 mg/L), while the lowest was at Station 3 (10.3 mg/L). The low TSS levels in the Karang Mumus River are influenced by slow water flow, which allows some TSS to settle, consistent with the findings of Pramaningsih et al. (2017). TSS levels are closely related to water clarity: lower TSS levels result in higher dissolved oxygen levels and better water clarity (Dewa et al., 2016). The TSS values in the Karang Mumus River are within acceptable limits for water quality Classes I–IV.

pH

pH is a parameter that determines the acidity or alkalinity of a water body. Extreme pH conditions can be harmful to aquatic organisms, as they can disrupt metabolism and respiration (Mainassy, 2017). Measured pH values ranged from 6.692 to 6.826 during high tide and from 6.742 to 6.968 during low tide. These values show little variation and are consistent with previous studies on the Karang Mumus River (Nisita et al., 2020). The pH of the river is influenced by domestic waste, which can raise pH levels. Extremely low pH can be lethal to organisms and increase the solubility of heavy metals in water (Kenconojati et al., 2016), whereas high pH can increase toxic ammonia concentrations (Tatangindatu et al., 2013). Based on Government Regulation No. 22 of 2021, the pH of the Karang Mumus River meets the standards for various water uses.

Dissolved Oxygen (DO)

DO is a measure of oxygen dissolved in water and indicates water quality. Higher DO levels signify better water quality (Prahutama, 2013). Oxygen is essential for respiration and metabolism in fish and other aquatic organisms (Haris et al., 2019).

DO levels met the water quality standards for Classes III–IV. The DO concentrations at the three stations during high and low tide ranged from 1.116 mg/L to 3.904 mg/L. The highest DO value was recorded at Station 3 during high tide (3.904 mg/L). High DO levels at Station 3 were influenced by temperature, TDS, and TSS, where lower temperature, TDS, and TSS contributed to increased DO levels, consistent with the findings of Listyaningrum (2022). Low DO levels in the Karang Mumus River were attributed to high COD levels, as noted in the study by Puspa et al. (2023). Additionally, the river's gentle morphology leads to slow water flow, reducing surface turbulence and oxygen mixing (Soewandita & Sudiana, 2010).

Biochemical Oxygen Demand (BOD)

BOD measures the amount of oxygen consumed by microorganisms to decompose organic matter in water (Santoso, 2018). The BOD5 levels in the Karang Mumus River ranged from 1.85 mg/L to 2.95 mg/L. The highest BOD5 value was recorded at Station 2 during high tide (2.95 mg/L), attributed to domestic waste from markets and households, consistent with Pramaningsih et al. (2017). The lowest BOD5 value was at Station 3 during high tide (1.85 mg/L). According to water quality standards, the BOD5 levels in the Karang Mumus River meet the requirements for Classes I–IV.

Chemical Oxygen Demand (COD)

COD represents the oxygen demand for chemical oxidation. COD values are always higher than BOD because most substances oxidize more readily through chemical processes than biological processes (Ashar et al., 2020). Laboratory analysis showed that COD levels in the Karang Mumus River were suitable for water quality standards of Classes II–IV, ranging from 30.93 mg/L to 45.83 mg/L. The highest COD value was at Station 2 during low tide (45.83 mg/L), likely due to the high input of domestic waste, consistent with Puspa et al. (2023). Slow water flow also contributed to high COD levels by hindering pollutant degradation (Sara et al., 2018).

Total Phosphate

Phosphates occur in water as orthophosphate, polyphosphate, and organic phosphate. High phosphate levels can disrupt aquatic ecosystems by promoting excessive algal growth, reducing sunlight penetration (Ngibad, 2019). Phosphate concentrations in the Karang Mumus River ranged from 0.043 mg/L to 0.118 mg/L, with the highest level at Station 2 during high tide (0.118 mg/L). This was attributed to industrial and domestic waste, consistent with Sanjaya et al. (2023).

Nitrate

Nitrate is the primary form of nitrogen in water and a key nutrient for plant and algae growth (Ramadhan & Yusanti, 2020). Nitrate levels ranged from 0.150 mg/L to 0.869 mg/L, with the highest concentration at Station 1 during high tide (0.869 mg/L). High nitrate levels were linked to human activities and seasonal fluctuations (Amalia et al., 2021). According to water quality standards, nitrate levels in the Karang Mumus River meet the requirements for Classes I–IV.

Pollution Index

The Pollution Index of the Karang Mumus River at each observation station is presented in Table 1 & Table 2. The water quality standards used follow Government Regulation No. 22 of 2021, Appendix VI, regarding river water quality standards.

Table 1. Pollution Index of Karang Mumus River at Each Station During High Tide (Water Quality Standards Class I-IV)

No.	Observation Station	Ci/Lij Max	Ci/Lij Average	PI	Category
1	Upstream	2.53	0.79	1.70	Lightly Polluted
2	Middle	2.27	0.76	1.51	Lightly Polluted
3	Downstream	1.76	0.58	1.17	Lightly Polluted

Table 2. Pollution Index of Karang Mumus River at Each Station During Low Tide (Water Quality Standards Class I-IV)

No.	Observation Station	Ci/Lij Max	Ci/Lij Average	PI	Category
1	Upstream	2.10	0.80	1.37	Lightly Polluted
2	Middle	2.33	0.87	1.53	Lightly Polluted
3	Downstream	1.96	0.71	1.29	Lightly Polluted

From Table 1 & Table 2, the calculation results of the Pollution Index at each station show a varying trend, ranging from 1.17 to 1.70. The level of pollution in the Karang Mumus River is influenced by conditions around each station, such as population density and activities that have the potential to pollute the waters.

During both high and low tide, Stations 1, 2, and 3 are categorized as lightly polluted. Among the measured parameters, the most significant contributors to the Pollution Index (Ci/Lij values) are Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD), as these parameters do not meet the established water quality standards (Class I & II). Consequently, the water quality is classified as lightly polluted at Stations 1 and 2.

Other parameters, including color, temperature, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Biochemical Oxygen Demand (BOD), total phosphate, and nitrate, meet the water quality standards for Classes I-IV.

CONCLUSION

The water quality parameters during tidal fluctuations that do not meet the Class I-II standards but comply with Class III-IV standards of Government Regulation No. 22 of 2021 are Dissolved Oxygen (DO) and Chemical Oxygen Demand (COD). Meanwhile, other parameters such as color, temperature, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Biochemical Oxygen Demand (BOD), total phosphate, and nitrate meet the Class I-IV standards.

There is a variation in the Pollution Index values between high and low tides. However, based on the analysis of 10 parameters (color, temperature, TDS, TSS, pH, DO, BOD, COD, total phosphate, and nitrate), the Karang Mumus River is categorized as meeting the quality standards but classified as lightly polluted.

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