GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gscarr.gsconlinepress.com/

(RESEARCH ARTICLE)

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STUDY OF WATER QUALITY AND WATER QUALITY STATUS USING THE STORET METHOD IN TENGGARONG RIVER, KUTAI KARTANEGARA REGENCY, EAST KALIMANTAN

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GSC Advanced Research and Reviews, 2026, 29(01), 256–264

Publication history: Received on 12 September 2026; revised on 18 October 2026; accepted on 20 October 2026

Article DOI: https://doi.org/10.30574/gscarr.2026.29.1.0281

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ABSTRACT

The Tenggarong River is an important water body in Kutai Kartanegara Regency, East Kalimantan, with ecological and social functions, including water supply for local communities. This study aimed to assess the river cross-sectional profile, evaluate water quality against the Class II standard in Appendix VI of Government Regulation No. 22 of 2021, and determine water quality status using the STORET method. Five sampling locations were selected: Saka Kanan, the Saka Kiri–Saka Kanan confluence, Bekotok Bridge, Bridge 3, and Bongkok Bridge. Sampling was conducted in two periods. Eight parameters were analyzed: TSS, pH, BOD, COD, DO, nitrate, total phosphate, and Fecal Coliform. Cross-sectional measurements were used to characterize wetted area and flow discharge. The wetted cross-sectional area ranged from 10.71 to 47.84 m^2 and discharge from 1.071 to 4.784 m^3/s. Most parameters complied with the Class II standard, but COD, nitrate, DO, and Fecal Coliform exceeded or fell outside the applicable criteria at several locations or periods. The maximum COD and nitrate concentrations were 64.22 and 54.05 mg/L, respectively, while the minimum DO was 3.23 mg/L. Fecal Coliform exceeded 1,000 MPN/100 mL at all sampling locations and reached 241,960 MPN/100 mL. STORET scores were -31, -27, -35, -37, and -32, indicating four heavily polluted locations and one moderately polluted location. Spatial regression produced R^2=0.014, suggesting that water quality status did not follow a simple linear downstream pattern.

Keywords: Water Quality; Tenggarong River; STORET; Fecal Coliform; Class II Standard; East Kalimantan

1 INTRODUCTION

Water is a fundamental component for the sustainability of ecosystems and human activities. Rivers do not only function as channels for water flow, but also as part of an ecological system that receives, transports, transforms, and distributes materials from catchment areas. Changes in land use, settlement growth, agricultural activities, and economic activities

can increase pressure on the quality of water bodies. Therefore, the evaluation of river water quality needs to consider physical, chemical, and microbiological characteristics in an integrated manner.

Rivers play a vital role as primary sources of clean water, supporting domestic needs, transportation, and regional development, particularly in areas undergoing urban expansion like Ujoh Bilang Village, the capital of Mahakam Ulu Regency. The Sebenaq River, a key tributary of the Mahakam River, is heavily utilized by local communities for raw water and daily activities due to the absence of a municipal water supply system (PDAM). However, ongoing infrastructure development, office construction, and growing residential and agricultural activities along the riverbanks threaten to degrade its water quality and alter its physical cross-sectional profile through increased pollution and sedimentation. Previous studies on river water quality assessment using the STORET and Pollution Index methods under Government Regulation No. 22 of 2021 (Class I) have demonstrated varying levels of contamination across regional water bodies. Therefore, a comprehensive study evaluating the water quality, pollution status, and riverbed cross-sectional profile of the Sebenaq River across seasonal variations is essential to establish baseline empirical data and support sustainable water resource management in Mahakam Ulu Regency.

The Tenggarong River is located in the Tenggarong watershed system, which has several tributaries, including Saka Kanan and Saka Kiri. The source thesis document states that the area of the Tenggarong watershed is approximately 31,546.978 ha and there are land cover changes related to agricultural and mining activities. These conditions have the potential to affect surface runoff, sediment transport, and the input of organic matter and nutrients into the river body. The Tenggarong River also has an important social function for the community in the Tenggarong area.

Water quality assessment needs to be compared with quality criteria corresponding to its designated use. In this study, the main reference is Appendix VI of Government Regulation Number 22 of 2021, specifically Class II. The parameters chosen follow those used in the study and the Environmental Quality Index framework, namely TSS, pH, BOD, COD, DO, nitrate, total phosphate, and Fecal Coliform. These parameters represent aspects of solids, acid-base conditions, organic matter load, dissolved oxygen, nutrients, and fecal contamination.

The STORET method is used to provide an integrated picture of water quality status by assigning scores to parameters that do not meet the quality standards. This approach is useful for comparing conditions between locations because parameter results with different units can be summarized into a quality status score. In this study, STORET analysis refers to the Decree of the Minister of State for the Environment Number 115 of 2003.

Previous studies on water quality in rivers in Kalimantan showed that anthropogenic pressure can produce different pollution patterns between locations and seasons. Studies on the Mahap River and Kahala River summarized in the thesis indicate that parameters such as BOD, COD, DO, metals, and domestic parameters can be limiting quality factors, while STORET results can vary from moderately polluted to heavily polluted. This demonstrates the importance of location-based evaluations for the Tenggarong River.

Based on these conditions, this study was directed to answer three main questions: (1) what are the characteristics of the cross-sectional profile and discharge of the Tenggarong River at the observation points; (2) which parameters do not meet Class II quality standards; and (3) what is the water quality status based on the STORET method and its spatial pattern. The objective of the study is to provide a scientific data foundation for understanding the water quality conditions of the Tenggarong River and supporting water quality management at the watershed level.

1.1 Novelty and Contribution Of The Study

The contribution of this study lies in combining simple hydromorphological characterization through cross-sectional profiles, evaluation of eight water quality parameters, and determination of water quality status using STORET at five locations in the Tenggarong River over two observation periods. This integration provides more operational information compared to merely presenting individual parameter concentrations. Furthermore, spatial relationship analysis between location order and STORET scores was used to assess whether quality degradation follows a linear trend from upstream to downstream.

2 RESEARCH METHOD

2.1 Study Design and Locations

The study utilized an observational-experimental approach through water sampling at five points along the Tenggarong River and water quality parameter testing at the UPTD Environmental Laboratory of the Environment and Forestry Office of Kutai Kartanegara Regency. Sampling was conducted twice: Period 1 on November 5, 2025, and Period 2 on April 14, 2026.

Table 1: Coordinates of The Sampling Site

Point	Location	Coordinates listed in the thesis
1	Saka Kanan	116.9453056; -0.439222
2	Saka Kiri–Kanan Confluence	116.9535; -0.4427
3	Bekotok Bridge	116.960313; -0.428718
4	Bridge 3	116.980021; -0.419337
5	Bongkok Bridge	116.9909445; -0.416388896

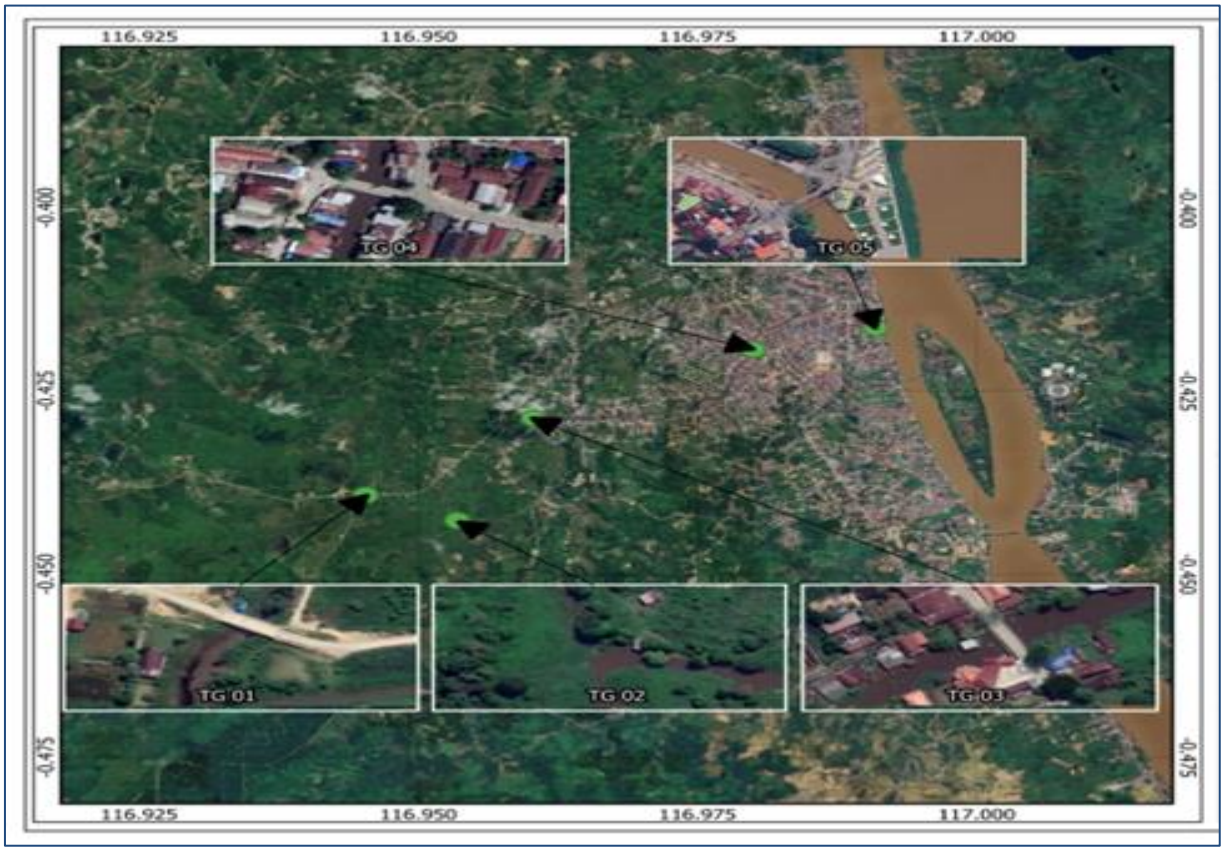


Figure 1: Sampling locations

2.2 Cross-Sectional Profile And Discharge Measurement

The river cross-sectional profile was measured using a cross-section approach to illustrate the shape of the wetted cross-section at each point. The cross-sectional area serves as the basis for describing local hydraulic characteristics. Research data produced wetted cross-sectional areas of 10.71 m^2 at Saka Kanan; 20.46 m^2 at the Saka Kiri–Kanan confluence; 30.82 m^2 at Bekotok Bridge; 32.34 m^2 at Bridge 3; and 47.84 m^2 at Bongkok Bridge. The reported discharges were 1.071, 2.046, 3.082, 3.234, and 4.784 m^3/s, respectively.

Differences in cross-sectional shapes are important in interpreting water quality because they affect mixing conditions, residence time, turbulence, and the potential for dilution. However, a cause-and-effect relationship between cross-sectional shape and pollutant concentration was not experimentally established in this study.

2.3 Sample Collection And Analysis

Water samples were analyzed for eight parameters: TSS, pH, BOD, COD, DO, nitrate (NO_3^-), total phosphate, and Fecal Coliform. Test methods listed in the thesis include SNI 6989.3:2019 for TSS, SNI 6989.11:2019 for pH, SNI 6989.72:2009 for BOD, SNI 6989.2:2019 for COD, SNI 06-6989.14-2004 for DO, IKA 6.4-23-LL for nitrate, SNI 6989.31:2021 for total phosphate, and SM 9223 B for Fecal Coliform.

Table 2: Environmental Quality Standards for Test Parameters

Parameter	Unit	Class II Standard	Test Method
TSS	mg/L	50	SNI 6989.3:2019
pH	-	6–9	SNI 6989.11:2019
BOD	mg/L	3	SNI 6989.72:2009
COD	mg/L	25	SNI 6989.2:2019
DO	mg/L	>4	SNI 06-6989.14-2004
Nitrate	mg/L	10	IKA 6.4-23-LL
Total phosphate	mg/L	0.2	SNI 6989.31:2021
Fecal Coliform	MPN/100 mL	1,000	SM 9223 B

2.4 STORET Water Quality Status Analysis

Water quality status was calculated using the STORET method according to Kepmen LH No. 115 of 2003. Parameters exceeding the quality standard were assigned penalty scores based on the type of violation and then summed into a score for each location. Categories used in the source document are: score 0 meets quality standard; -1 to -10 slightly polluted; -11 to -30 moderately polluted; and score ≤ -31 heavily polluted.

Table 3: Water Quality Class Classification (Source: KepMenLH No. 115 of 2003)

No.	Class	Score	Water Quality Status
1	Class A	0	Meets Quality Standard
2	Class B	-1 to -10	Slightly Polluted
3	Class C	-11 to -30	Moderately Polluted
4	Class D	≥ -31	Heavily Polluted

In addition to classification, the source study analyzed the spatial relationship between sampling location order and STORET scores using linear regression. The coefficient of determination was used to describe the proportion of score variation that could be explained by sampling point position. A low R^2 value was interpreted as an indication that local factors were potentially more dominant than a linear trend along the streamflow.

3 RESULTS

3.1 Cross-Sectional Profile And Discharge

Measurement results showed variations in wetted cross-sectional area among points. The area increased from 10.71 m^2 at Saka Kanan to 47.84 m^2 at Bongkok Bridge. In the research dataset, the reported discharge increased sequentially from 1.071 m^3/s to 4.784 m^3/s. This pattern illustrates differences in geometric and flow conditions at the observation points.

Table 4: Geometric and Flow Conditions at The Sampling Site

Point	Location	Wetted cross-sectional area (m^2)	Discharge (m^3/s)	Cross-sectional character
1	Saka Kanan	10.71	1.071	Uneven concave
2	Saka Kiri–Kanan Confluence	20.46	2.046	Relatively steep bank; gentle bottom
3	Bekotok Bridge	30.82	3.082	Irregular concave/gentle V
4	Bridge 3	32.34	3.234	Irregular gentle V/trapezoid

5	Bongkok Bridge	47.84	4.784	Concave; deepest at center

These variations are important in the context of interpreting pollutant concentrations. Cross-section and discharge can influence dilution and transport, but the research data does not yet cover all hydrodynamic components required to calculate total pollutant loads completely. Therefore, measured concentrations are more appropriately used as indicators of quality conditions at the time of sampling rather than as annual pollutant load estimates.

3.2 Period 1 Water Quality

Table 5: Results of Water Quality Parameter Tests for Period 1

Parameter	Point 1	Point 2	Point 3	Point 4	Point 5	Quality Standard
TSS (mg/L)	37.25	31.50	9.25	35.25	31.71	50
pH	8.23	8.03	8.24	8.07	7.96	6–9
BOD (mg/L)	2.11	1.30	2.02	2.00	2.52	3
COD (mg/L)	17.27	36.87	35.79	29.00	31.95	25
DO (mg/L)	6.93	5.02	6.37	5.09	5.38	>4
Nitrate (mg/L)	50.77	11.06	54.05	42.57	39.29	10
Total phosphate (mg/L)	0.010	0.150	0.050	0.090	0.100	0.2
Fecal Coliform MPN/100 mL	1,123.6	2,649.1	1,555.3	241,960.0	54,750	1,000

*Quality standards based on Class II Appendix VI Government Regulation Number 22 of 2021.

In Period 1, pH, BOD, DO, TSS, and total phosphate were within the Class II quality standard ranges at all points. Conversely, COD exceeded 25 mg/L at points 2–5, while nitrate exceeded 10 mg/L at all points. Fecal Coliform also exceeded 1,000 MPN/100 mL at all locations, with an extreme value of 241,960 MPN/100 mL at Bridge 3. This value represents one of the most prominent findings in the study.

3.3 Period 2 Water Quality

Table 6: Results of Water Quality Parameter Tests for Period 1

Parameter	Point 1	Point 2	Point 3	Point 4	Point 5	Quality Standard
TSS (mg/L)	33.0	29.0	30.0	37.0	34.0	50
pH	8.10	7.91	7.84	7.82	7.72	6–9
BOD (mg/L)	0.59	0.79	1.00	1.20	1.30	3
COD (mg/L)	34.84	47.98	51.85	64.22	40.63	25
DO (mg/L)	5.48	4.59	4.16	3.36	3.23	>4
Nitrate (mg/L)	7.95	8.07	15.51	17.95	8.20	10
Total phosphate (mg/L)	0.075	0.088	0.118	0.122	0.129	0.2
Fecal Coliform MPN/100 mL	6,016.5	6,498.5	8,664.5	9,931.5	7,068.0	1,000

*Quality standards based on Class II Appendix VI Government Regulation Number 22 of 2021.

In Period 2, TSS, pH, BOD, and total phosphate remained within Class II criteria. COD exceeded quality standards at all points, reaching a maximum concentration of 64.22 mg/L at Bridge 3. Nitrate exceeded standards at points 3 and 4, with values of 15.51 and 17.95 mg/L, respectively. DO fell below the minimum threshold of 4 mg/L at points 4 and 5, recorded at 3.36 and 3.23 mg/L, respectively. Fecal Coliform again exceeded quality standards at all points, ranging from 6,016.5 to 9,931.5 MPN/100 mL.

3.4 Inter-Period Comparison

Inter-period changes indicate that pollution patterns were not uniform. Nitrate was exceptionally high during Period 1, particularly at points 1, 3, 4, and 5, but decreased during Period 2 at points 1, 2, and 5. In contrast, COD increased across

all points in Period 2. Fecal Coliform increased at all locations during Period 2 compared to Period 1, whereas BOD was noticeably lower. This pattern suggests that parameters exhibit distinct temporal responses to hydrological conditions and pollutant inputs.

Table 7: Inter-period Comparison of COD, Nitrate, DO and Fecal Coliform Parameters

Parameter	Period 1 Pattern	Period 2 Pattern	Data-Based Interpretation
COD	17.27–36.87 mg/L; several points > QS	34.84–64.22 mg/L; all points > QS	Oxidizable load increased in Period 2
Nitrate	11.06–54.05 mg/L; majority > QS	7.95–17.95 mg/L; points 3–4 > QS	Temporal/diffuse fluctuation
DO	5.02–6.93 mg/L	3.23–5.48 mg/L	Decline at points 4–5
Fecal Coliform	1,123.6–241,960	6,016.5–9,931.5	Persistent and increased in Period 2

3.5 Water Quality Status Based On STORET

Table 8: Water Quality Status Based on STORET

Point	Location	STORET Score	Status
1	Saka Kanan	-31	Heavily Polluted
2	Saka Kiri–Kanan Confluence	-27	Moderately Polluted
3	Bekotok Bridge	-35	Heavily Polluted
4	Bridge 3	-37	Heavily Polluted
5	Bongkok Bridge	-32	Heavily Polluted

Four out of five points fell into the Heavily Polluted category, while the Saka Kiri–Saka Kanan confluence fell into Moderately Polluted. The lowest score was -37 at Bridge 3. These values are consistent with the presence of several parameters failing to meet quality standards, notably COD and Fecal Coliform, alongside low DO levels in Period 2. (https://docs.google.com/spreadsheets/d/1KPddYKOy-ZRcOwi0WL0l9zaDEmpa0lUc/edit?gid=494542763#gid=494542763)

4 DISCUSSION

4.1 Dominance of COD and implications of organic load

COD serves as an indicator of oxygen demand required to chemically oxidize materials. In this study, COD exceedances occurred at several points in Period 1 and across all points in Period 2. The maximum value of 64.22 mg/L at Bridge 3 reflects a condition with a relatively high oxidizable load during sampling. An increase in COD without a proportional rise in BOD during Period 2 also indicates that COD cannot be interpreted solely as biodegradable organic matter; the chemically oxidizable fraction can comprise broader components.

These findings need to be read alongside DO parameters. At Bridge 3, COD of 64.22 mg/L was associated with DO of 3.36 mg/L, while Bongkok Bridge exhibited COD of 40.63 mg/L and DO of 3.23 mg/L in Period 2. Ecologically, low DO conditions can limit oxygen-dependent organisms. However, as this study is observational and restricted to two sampling periods, a direct causal relationship between COD and DO cannot be proven solely from these paired datasets.

4.2 Dynamics of nitrate and nutrients

Nitrate exhibited a clear contrast between periods. Period 1 recorded high concentrations, reaching a peak of 54.05 mg/L at Bekotok Bridge, whereas during Period 2, only points 3 and 4 exceeded the quality standard. This change highlights temporal variability. In a watershed context, nitrate can originate from land runoff, agricultural activities,

decomposed organic matter, and domestic sources. The thesis document links these fluctuations to nutrient input and activity levels around the watershed.

Total phosphate was relatively low, with all reported values falling below 0.2 mg/L. Consequently, phosphate was not a major limiting parameter in determining STORET status in this dataset. Although nitrate and phosphate are nutrients associated with eutrophication, conclusions regarding actual eutrophication require supplementary data such as chlorophyll-a, phytoplankton biomass, or primary productivity observations.

4.3 Fecal Coliform as an indicator of microbiological pollution

Fecal Coliform was the parameter that most consistently exceeded quality standards. All locations across both periods showed values above 1,000 MPN/100 mL. Period 1 displayed an extreme value of 241,960 MPN/100 mL at Bridge 3, while Period 2 recorded a range of 6,016.5–9,931.5 MPN/100 mL. The persistent exceedance at all points demonstrates that fecal contamination is a widespread issue not confined to a single location.

High Fecal Coliform levels are generally consistent with potential influences from domestic activities and sanitation along riverbanks, as discussed in the thesis. However, specific sources cannot be confirmed from microbiological data alone. For robust source identification, future research should incorporate microbial source tracking, additional indicators, and inventory surveys of drainage outlets and sanitation facilities.

4.4 Relationship between water quality and hydrological conditions

Variations in discharge and cross-sectional area indicate that hydrological conditions differed across points. Theoretically, increased discharge can lead to the dilution of pollutant concentrations, but it can also enhance pollutant transport from land into the river during runoff events. The research dataset reveals that not all parameters follow the exact same hydrological pattern. Therefore, water quality interpretation should simultaneously consider discharge, rainfall, land use, and local pollution sources.

Differences between Period 1 and Period 2 reinforce the necessity of multi-season sampling. In Period 1, nitrate was exceptionally high, whereas in Period 2, COD and Fecal Coliform were more prominent, and DO decreased at two points. Although two periods are insufficient to capture full annual dynamics, they adequately demonstrate that quality status can change in a parameter-specific manner.

4.5 Spatial patterns of quality status

The obtained STORET scores were -31, -27, -35, -37, and -32 from point 1 through point 5. This pattern does not show a monotonic change from upstream to downstream. In fact, the Saka Kiri–Saka Kanan confluence point scored -27, which is better than the other four points, while Bridge 3 had the lowest score of -37.

Regression analysis reported in the thesis yielded a Pearson correlation coefficient of approximately 0.117, a slope of 0.4, an intercept of -32, and an R^2 of 0.014. The R^2 value signifies that only about 1.4% of the variation in STORET scores can be explained by sampling position sequence in a simple linear model. These results support the interpretation that changes in quality status are inadequately explained by longitudinal position alone. Local sources, variations in surrounding activities, hydrological characteristics, and tributary inputs must be considered.

Nonetheless, statistical interpretation must account for the very small sample size of five locations. With n=5, the regression model provides only an initial indication and is insufficient for strong statistical generalization. Future research should increase the number of sampling locations and periods while testing additional explanatory variables.

4.6 Comparison with previous studies

The findings of this study generally align with water quality studies on the Mahap River and Kahala River summarized in the thesis, which indicate that rivers in Kalimantan can experience quality status variations from moderately polluted to heavily polluted, with limiting parameters varying by location. These differences highlight that watershed characteristics, community activities, land use, and local pollution sources are crucial in determining water quality conditions.

The source study also compared findings with research on the Mahakam River in urban areas and national literature on river quality. The primary similarity is the emergence of organic matter and microbiological parameters as key indicators of anthropogenic pressure. However, this article does not generalize the Tenggarong River results to all Kalimantan rivers due to the limited scope of locations and study periods.

4.7 Management implications

Consistently high Fecal Coliform findings provide a basis for prioritizing domestic source control and sanitation. Relevant management measures based on thesis recommendations include developing domestic wastewater management systems, improving sanitation for riverbank communities, controlling direct waste disposal, and conducting regular monitoring.

For COD and nitrate parameters, management should focus on identifying organic and nutrient sources, including runoff from built-up areas, agricultural activities, and other local sources identified through field surveys. Establishing pollution load capacity and water quality modeling can serve as subsequent steps once discharge data, source loads, and hydraulic characteristics become available.

5 CONCLUSION

The study shows that the Tenggarong River exhibits noticeable variations in cross-sectional profiles across observation points, with wetted cross-sectional areas ranging from 10.71 to 47.84 m^2 and reported discharge from 1.071 to 4.784 m^3/s. Variations in cross-sectional shape provide a hydrological context for interpreting water quality distribution.

Of the eight parameters analyzed, TSS, pH, BOD, and total phosphate generally met Class II quality standards in the research dataset. Parameters of primary concern are COD, nitrate, DO, and Fecal Coliform. COD reached 64.22 mg/L, nitrate reached 54.05 mg/L, and DO reached a minimum of 3.23 mg/L. Fecal Coliform exceeded 1,000 MPN/100 mL at all points across both periods, reaching a maximum value of 241,960 MPN/100 mL.

Based on STORET, Saka Kanan (-31), Bekotok Bridge (-35), Bridge 3 (-37), and Bongkok Bridge (-32) fell into the Heavily Polluted category, whereas the Saka Kiri–Saka Kanan confluence (-27) was categorized as Moderately Polluted. Spatial patterns were non-linear; an R^2 of 0.014 indicates that sampling point position accounts for only a tiny fraction of score variation in a simple linear model.

From a management perspective, research results support the necessity of periodic water quality monitoring, domestic pollution source control, sanitation improvements, organic and nutrient runoff control, and further studies regarding pollution load capacity.

Research limitations

The primary limitation of this study is the relatively small number of sampling points and periods, meaning the results do not fully capture annual variations. The study also did not calculate pollutant loads from individual sources or microbiologically identify the specific origins of Fecal Coliform. Therefore, management recommendations should be viewed as data-driven initial directions rather than definitive identifications of single pollution sources.

Recommendations for future research

Future research should increase sampling frequency during peak rainy and dry seasons, add sampling points at potential input sources, conduct simultaneous discharge measurements alongside sampling, and include parameters such as ammonia, nitrite, chlorophyll-a, and additional microbiological indicators where relevant. QUAL2K modeling or Streeter–Phelps models can be utilized to evaluate oxygen dynamics and pollution load capacity once required input data is available.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflict of interest regarding the publication of this article.

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