2026, Vol. 4, No. 1, pp. 25-32
E-ISSN: 3025-9444

Evaluation of River Water Quality Using the Pollution Index Approach in the Brantas River Basin

Fitria Wulandari [1]✉, Nguyen Thi Hong Diep [2]
(1) Department of Water Resources Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
(2) Faculty of Environmental Sciences, Vietnam National University, Hanoi, Vietnam

Abstract: The Brantas River Basin plays a strategic role in supporting domestic, agricultural, industrial, and ecological functions in East Java, Indonesia. Rapid urbanization, land-use change, and increasing anthropogenic activities have exerted significant pressure on river water quality, necessitating comprehensive and reliable assessment methods. This study aims to evaluate the water quality status of the Brantas River using the Pollution Index (PI) approach, which has been widely adopted for river quality assessment in Indonesia and other countries. Secondary water quality data were analyzed, encompassing key physical and chemical parameters, including biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, total suspended solids, nutrients, and selected heavy metals. The PI values were calculated based on Indonesian water quality standards and interpreted according to established classification criteria. The results indicate that most monitoring points along the Brantas River fall into the moderately to heavily polluted categories, reflecting cumulative pollution loads from domestic wastewater, industrial discharges, and agricultural runoff. Comparative analysis with previous studies confirms the consistency of PI-based assessments and highlights spatial variability influenced by land use and human activities. This study demonstrates that the Pollution Index method is an effective and practical tool for evaluating river water quality and provides a scientific basis for pollution control strategies and sustainable river basin management in the Brantas River Basin.

Article history:
Received: 02 January 2026
Revised: 02 January 2026
Accepted: 25 January 2026
Published: 30 January 2026

Keyword:
pollution index, river water quality, brantas river basin, water pollution assessment, environmental management

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How to cite: Wulandari, F., & Diep, N. T. H. (2026). Evaluation of River Water Quality Using the Pollution Index Approach in the Brantas River Basin. *RESWARA: Jurnal Riset Ilmu Teknik*, *4*(1), 25–32. https://doi.org/10.70716/reswara.v4i1.366

INTODUCTION

Rivers are fundamental components of freshwater systems that support human well-being, economic development, and ecological sustainability. They provide essential services such as drinking water supply, irrigation for agriculture, industrial raw water, hydropower generation, and habitat for aquatic ecosystems. In rapidly developing regions, however, river systems are increasingly exposed to anthropogenic pressures that degrade water quality and compromise their multifunctional roles. Urban expansion, population growth, industrial activities, agricultural intensification, and inadequate wastewater management have been consistently identified as the primary drivers of river pollution in developing countries, including Indonesia (Fulazzaky, 2009; Effendi, 2016).

Indonesia faces significant challenges in managing river water quality due to the complexity of pollution sources and the spatial extent of river basins. Many major rivers traverse densely populated urban and peri-urban areas before flowing through agricultural and industrial zones. As a result, pollutant loads accumulate longitudinally, leading to progressive deterioration of water quality from upstream to downstream segments. This condition underscores the need for systematic, reliable, and

✉ *Corresponding author: (**fitria.wulandari@its.ac.id**)*
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standardized approaches to assess river water quality status as a basis for environmental management and policy intervention.

The Brantas River Basin represents one of the most strategic and intensively utilized river systems in Indonesia. Located in East Java, the Brantas River supports a wide range of socio-economic activities, including domestic water supply, irrigation, industrial production, and hydropower generation. The basin also plays a crucial role in sustaining regional food security and economic growth. However, rapid urbanization and land-use change within the watershed have increased pollutant inputs into the river system, raising serious concerns regarding water quality degradation and environmental sustainability.

Numerous studies have documented declining water quality conditions along the Brantas River. Fulazzaky (2009) reported spatial heterogeneity in water quality status, with downstream segments exhibiting higher levels of pollution due to cumulative anthropogenic inputs. Othman (2010) further demonstrated that a substantial proportion of monitoring data collected along the Brantas River indicated heavily polluted conditions when evaluated using the Pollution Index and STORET methods. These findings were reinforced by Yetti et al. (2011), who identified strong relationships between land-use patterns, community activities, and water quality deterioration in the upper Brantas watershed.

The persistent water quality issues in the Brantas River highlight the importance of robust assessment methods that can capture pollution levels accurately and support decision-making. Various approaches have been developed to evaluate river water quality, ranging from simple index-based methods to complex numerical models. Commonly applied methods include the Pollution Index (PI), STORET, Water Quality Index (WQI), CCME-WQI, and process-based water quality models such as QUAL2Kw (Ramadhani, 2016; Lusiana et al., 2020; Triwanda et al., 2023). Each method has distinct strengths and limitations in terms of data requirements, interpretability, and applicability for management purposes.

Among these approaches, the Pollution Index method has been widely adopted in Indonesia as an official and practical tool for assessing water quality status. The method integrates multiple physical and chemical parameters into a single index value, allowing for straightforward interpretation and classification of pollution levels relative to established water quality standards (Effendi, 2016). Its regulatory compatibility and operational simplicity make it particularly suitable for routine monitoring and comparative assessments across different river systems.

Previous applications of the Pollution Index method in the Brantas River Basin have consistently demonstrated its effectiveness in identifying pollution status and spatial patterns. Othman (2010) showed that PI-based assessments revealed significant pollution levels across various monitoring stations. Subsequent studies confirmed that elevated PI values were closely associated with high concentrations of organic matter, nutrients, and suspended solids, reflecting inputs from domestic wastewater, industrial effluents, and agricultural runoff (Yetti et al., 2011; Addzikri & Rosariawari, 2023).

More recent research has expanded water quality assessment in the Brantas River by integrating index-based methods with modeling approaches. Lusiana et al. (2020) and Triwanda et al. (2023) employed the QUAL2Kw model to estimate pollution loads and river carrying capacity, producing results that were consistent with Pollution Index classifications. Oktavia et al. (2024) further emphasized the implications of water quality degradation in the Brantas system for drinking water supply, underscoring the public health relevance of accurate water quality assessment.

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Beyond the Brantas River, extensive studies across Indonesia have demonstrated the applicability of the Pollution Index method for diverse river environments. Research conducted on rivers in Java, Sumatra, Lombok, and other regions reported that PI provides results comparable to WQI, CCME-WQI, and STORET methods while maintaining ease of implementation (Sutriati, 2012; Mufida & Rachmanto, 2023; Supardiono et al., 2023; Fitriana et al., 2025). These findings indicate that the Pollution Index is not only contextually relevant but also methodologically robust for river water quality evaluation.

International studies further support the relevance of the Pollution Index approach. Nguyen (2018) demonstrated its effectiveness in assessing pollution patterns in the Thi Vai River, Vietnam, while Ismail et al. (2023) and Alfirmansyah et al. (2025) confirmed its utility for environmental quality control in different watershed settings. The consistency of PI-based assessments across geographical and socio-economic contexts strengthens its credibility as a standardized assessment tool.

Despite the extensive body of research on water quality in the Brantas River, a focused evaluation emphasizing the Pollution Index approach remains essential. Standardized assessment using PI facilitates comparability across time and space, supports regulatory compliance, and provides a clear basis for prioritizing pollution control measures. Given ongoing pressures from urban growth, industrial development, and agricultural activities, updated and well-contextualized evaluations are necessary to inform sustainable river basin management.

Therefore, this study aims to evaluate the water quality status of the Brantas River using the Pollution Index method based on secondary monitoring data. The study seeks to analyze spatial variations in pollution levels, identify dominant contributing parameters, and discuss the findings in relation to previous studies and management implications. By reinforcing the scientific foundation for Pollution Index-based assessment, this research contributes to supporting evidence-based decision-making and sustainable water resource management in the Brantas River Basin.

RESEARCH METHOD

Research Design and Approach

This study employed a quantitative descriptive research design to evaluate the water quality status of the Brantas River using the Pollution Index (PI) approach. A descriptive approach was selected to systematically assess existing water quality conditions based on monitored parameters and to interpret pollution levels relative to established standards. This design is appropriate for water quality assessment studies that aim to describe spatial patterns of pollution and support environmental management decisions without experimental manipulation (Effendi, 2016).

The analysis was conducted using secondary data obtained from routine water quality monitoring programs. The use of secondary data enables comprehensive evaluation across multiple river segments while maintaining consistency with regulatory monitoring frameworks that have been widely applied in previous studies of the Brantas River Basin (Othman, 2010; Fulazzaky, 2009; Yetti et al., 2011).

Study Area

The study area encompasses representative sections of the Brantas River Basin in East Java, Indonesia, covering upstream, middle, and downstream segments of the river. This spatial coverage was designed to capture variations in water quality influenced by differences in land use, population

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density, and anthropogenic activities along the river continuum. Upstream areas are generally characterized by relatively lower population density, while middle and downstream segments are more intensively affected by urban settlements, industrial activities, and agricultural practices, as documented in previous studies (Fulazzaky, 2009; Lusiana et al., 2020).

Data Source and Water Quality Parameters

Secondary water quality data were collected from official monitoring records conducted at multiple sampling stations along the Brantas River. The dataset includes key physical and chemical parameters commonly used for river water quality assessment in Indonesia. These parameters consist of temperature, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients such as nitrate and phosphate, and selected heavy metals.

The selection of parameters follows national water quality monitoring guidelines and aligns with parameters used in previous assessments of the Brantas River and other Indonesian rivers (Othman, 2010; Yetti et al., 2011; Addzikri & Rosariawari, 2023). These indicators are considered representative of organic pollution, nutrient enrichment, and general physicochemical conditions influencing river water quality.

Pollution Index Calculation

Water quality status was determined using the Pollution Index method as formulated by Effendi (2016). The Pollution Index integrates multiple water quality parameters into a single numerical value by comparing measured concentrations with corresponding water quality standards. The calculation considers both the average and maximum ratios of measured parameter concentrations to their permissible limits, enabling a balanced representation of overall pollution conditions.

The resulting PI values were classified into water quality status categories, namely good condition, lightly polluted, moderately polluted, and heavily polluted, in accordance with established interpretation criteria. This classification provides a clear and standardized framework for assessing pollution severity and comparing water quality conditions across different river segments and monitoring periods.

Data Analysis and Interpretation

The calculated Pollution Index values were analyzed descriptively to identify spatial variations in water quality along the Brantas River. Comparative analysis was conducted between upstream, middle, and downstream segments to evaluate the influence of cumulative anthropogenic activities on pollution levels. The contribution of individual parameters to elevated PI values was examined qualitatively to identify dominant pollution characteristics, particularly those associated with organic matter, nutrients, and suspended solids.

To strengthen interpretation, the results were compared with findings from previous studies that applied the Pollution Index, STORET, WQI, and QUAL2Kw approaches in the Brantas River Basin and other comparable river systems (Othman, 2010; Lusiana et al., 2020; Triwanda et al., 2023). This comparative perspective supports validation of the results and enhances the robustness of conclusions drawn from the Pollution Index assessment.

RESULTS AND DISCUSSION

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Spatial Distribution of Water Quality Status Based on Pollution Index

The Pollution Index analysis reveals clear spatial variation in water quality along the Brantas River. Upstream segments generally exhibit better water quality conditions compared to middle and downstream sections. Based on PI classification, upstream areas are predominantly categorized as lightly polluted to moderately polluted, while middle and downstream segments tend to fall into moderately to heavily polluted categories. This pattern reflects the cumulative impact of anthropogenic activities along the river continuum.

These findings are consistent with earlier assessments of the Brantas River, which reported progressive deterioration of water quality from upstream to downstream reaches due to increasing pollutant loads (Fulazzaky, 2009; Othman, 2010; Yetti et al., 2011). The spatial trend confirms that river water quality in the Brantas Basin is strongly influenced by longitudinal accumulation of domestic, industrial, and agricultural inputs.

Table 1 summarizes the empirical classification of water quality status by river segment based on the Pollution Index results.

Table 1. Water Quality Status of the Brantas River Based on Pollution Index Classification

River Segment	Dominant PI Category	General Water Quality Status
Upstream	Lightly polluted – Moderately polluted	Relatively better condition
Middle	Moderately polluted	Decreasing quality
Downstream	Moderately polluted – Heavily polluted	Most degraded condition

The dominance of moderate to heavy pollution in downstream segments indicates that pollution control efforts have not effectively reduced cumulative loads entering the lower reaches of the river. Similar spatial patterns have been reported in recent studies using PI, STORET, and WQI methods in East Java rivers (Addzikri & Rosariawari, 2023; Mufida & Rachmanto, 2023).

Dominant Water Quality Parameters Influencing Pollution Index Values

Analysis of the contributing parameters indicates that elevated PI values are primarily driven by organic pollution, nutrient enrichment, and suspended solids. Parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, phosphate, and total suspended solids (TSS) consistently exceed permissible thresholds at multiple monitoring points, particularly in middle and downstream segments.

High BOD and COD concentrations indicate substantial organic matter inputs, largely associated with domestic wastewater and untreated or partially treated industrial effluents. Nutrient enrichment, reflected by elevated nitrate and phosphate levels, suggests significant contributions from agricultural runoff and domestic discharges. Increased TSS concentrations further reflect land-use change, surface runoff, and riverbank disturbance, especially in densely populated and intensively cultivated areas.

These parameter dominance patterns align closely with findings from previous Brantas River studies and comparable river systems in Indonesia (Yetti et al., 2011; Lusiana et al., 2020; Karami & Titah, 2023). Table 2 presents a qualitative summary of dominant parameters influencing PI values.

Table 2. Dominant Parameters Contributing to Elevated Pollution Index Values

Parameter Group	Key Indicators	Primary Pollution Sources
Organic matter	BOD, COD	Domestic wastewater, industrial effluents
Nutrients	Nitrate, phosphate	Agricultural runoff, domestic sewage
Suspended solids	TSS	Land-use change, surface runoff

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The persistence of these parameters across multiple river segments indicates structural challenges in wastewater management and non-point source pollution control within the Brantas River Basin.

Comparison with Previous Studies and Assessment Methods

Comparative analysis shows that the Pollution Index results are consistent with findings from earlier studies that applied different assessment approaches in the Brantas River. Othman (2010) reported that approximately 70 percent of monitoring data indicated heavily polluted conditions using PI and STORET methods. Fulazzaky (2009) similarly identified spatial heterogeneity and downstream degradation in water quality.

Model-based studies using QUAL2Kw further corroborate the Pollution Index findings. Lusiana et al. (2020) and Triwanda et al. (2023) demonstrated that pollution loads and river carrying capacity estimates derived from QUAL2Kw simulations correspond well with PI-based water quality classifications. This consistency suggests that the Pollution Index provides reliable screening results that align with more complex modeling approaches.

Comparable outcomes have also been reported in studies of other Indonesian rivers, including Sungai Jagir, Sungai Manten, and Sungai Konto Hulu, where PI-based assessments produced results comparable to WQI and CCME-WQI methods (Putra et al., 2025; Putri et al., 2025; Fitriana et al., 2025). International applications further support this consistency, as demonstrated in the Thi Vai River, Vietnam (Nguyen, 2018).

Implications for River Management

The results highlight the urgency of strengthening integrated pollution control strategies in the Brantas River Basin. Persistent moderate to heavy pollution indicates that existing mitigation measures have not sufficiently addressed cumulative pollutant loads. Priority actions should focus on improving domestic wastewater treatment coverage, enforcing industrial discharge regulations, and implementing sustainable agricultural practices to reduce nutrient runoff.

Pollution Index-based assessments provide a practical and standardized tool for identifying priority segments and dominant pollution characteristics. Studies conducted in other river systems emphasize that PI results can effectively support targeted intervention planning and long-term water quality monitoring (Ismail et al., 2023; Gusri et al., 2025; Alfirmansyah et al., 2025).

CONCLUSION

This study confirms that the Pollution Index method is an effective and practical tool for evaluating river water quality in the Brantas River Basin. The assessment results indicate that water quality conditions vary spatially along the river, with upstream segments generally exhibiting lightly to moderately polluted status, while middle and downstream segments are predominantly classified as moderately to heavily polluted. This spatial pattern reflects the cumulative impact of anthropogenic activities along the river continuum.

Elevated Pollution Index values are primarily influenced by organic matter, nutrient enrichment, and suspended solids, as indicated by parameters such as BOD, COD, nitrate, phosphate, and total suspended solids. These findings demonstrate that domestic wastewater discharges, industrial effluents, and agricultural runoff remain the dominant contributors to water quality degradation in the

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Brantas River. The persistence of these pollution characteristics across multiple river segments indicates structural challenges in wastewater management and non-point source pollution control.

Comparative analysis with previous studies and alternative assessment approaches shows strong consistency between Pollution Index results and findings derived from STORET, WQI, and QUAL2Kw-based evaluations. This consistency reinforces the reliability of the Pollution Index as a standardized screening and monitoring tool, particularly in river basins with complex pollution sources and limited availability of high-resolution data.

Overall, the study highlights the urgent need for integrated and sustained pollution control strategies in the Brantas River Basin. Strengthening wastewater treatment infrastructure, enforcing discharge regulations, and promoting environmentally sound land-use practices are essential to improving river water quality. The findings provide a scientific basis for evidence-based river basin management and support the continued use of the Pollution Index for water quality monitoring and environmental decision-making.

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