Analysis of Tawangsari River Water Quality Using the Pollution Index Method in Sidoarjo Regency, Indonesia, during the 2024 Observation Period

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Abstract

River water quality assessment is a fundamental component of environmental management, particularly for rivers with the potential to serve as raw water sources. The Tawangsari River in Sidoarjo Regency, Indonesia, is influenced by domestic and surrounding land-use activities that may contribute to water quality degradation. This study aims to assess the water quality status of the Tawangsari River using the Pollution Index (PI) method during the 2024 observation period. Water samples were collected at three monitoring points representing upstream, middle, and downstream river segments. The analyzed parameters included pH, turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The results show that the Pollution Index values range from 2.245 to 6.439, classifying the river water quality from lightly polluted to moderately polluted, with the highest PI value observed at the middle segment of the river. Dissolved oxygen was identified as the dominant parameter influencing the Pollution Index values. From a management perspective, the findings indicate that pollution control efforts should prioritize the middle segment of the river through improved domestic wastewater management and routine dissolved oxygen monitoring. Despite the limited number of monitoring points and the single observation period, this study provides a practical baseline for river water quality management and future monitoring programs.

Keywords: *Dissolved oxygen; Environmental monitoring; Pollution index; River water quality; Water quality management*

1. Introduction

Rivers are essential components of the hydrological system that function as water sources for domestic, agricultural, and industrial needs. However, increasing human activities within river catchment areas often lead to water quality degradation due to the discharge of domestic wastewater and other environmental activities. Therefore, periodic river water quality monitoring is necessary to support sustainable water resource management.

The Tawangsari River plays an important role for the surrounding community. Settlement activities and environmental pressures along the riverbanks potentially contribute to pollution loads entering the river system. To assess the current condition of river water quality, an evaluation method capable of quantitatively and comprehensively describing water quality status is required. The Pollution Index (PI) method is widely applied to determine water pollution levels based on compliance with established water quality standards.

This study aims to analyze the water quality status of the Tawangsari River using the Pollution Index method as a basis for environmental monitoring and river water management.

To date, numerous studies have applied water quality indices to evaluate river pollution in Indonesia, particularly in urban and peri-urban areas. Previous research has demonstrated that domestic activities remain a dominant source of river pollution, often reflected in elevated organic loads and

reduced dissolved oxygen concentrations. However, many existing studies focus primarily on large river systems or employ extensive datasets that may not be readily applicable to smaller or local-scale rivers.

Previous studies have widely applied water quality indices, including the Pollution Index method, to assess river pollution in various regions of Indonesia. These studies generally report that domestic activities and land-use changes contribute significantly to river water quality degradation, often reflected in elevated pollution index values and reduced dissolved oxygen concentrations. However, most existing studies focus on large river systems or are conducted using extensive datasets over multiple monitoring periods.

Recent studies have demonstrated the effectiveness of the Pollution Index method in integrating multiple water quality parameters into a single index for environmental assessment. Nevertheless, there remains a limited number of studies that emphasize the application of the Pollution Index method at a local scale with a focus on identifying dominant parameters and management implications under conditions of limited monitoring data. In particular, studies that explicitly link Pollution Index results with practical river management priorities at the local level are still relatively scarce.

In this context, the present study addresses this gap by applying the Pollution Index method to assess the water quality status of the Tawangsari River in Sidoarjo Regency, Indonesia, during a single observation period. The novelty of this study lies in its emphasis on identifying dissolved oxygen as a dominant parameter influencing Pollution Index values and in translating the assessment results into practical management implications for river segments subjected to higher anthropogenic pressure. By focusing on a small to medium-scale river and limited monitoring points, this study provides a practical and replicable framework for local river water quality assessment and management, particularly in areas with constrained monitoring resources.

2. Method

This study employed a case study approach by collecting water quality samples at three monitoring points along the Tawangsari River, representing upstream, middle, and downstream conditions. The analysis of water quality status was conducted using the Pollution Index method by comparing measured water quality parameters with applicable water quality standards.

Sampling locations were selected to represent different land-use characteristics along the river. Water quality analysis was conducted in an accredited laboratory, and Pollution Index values were calculated following the procedure stipulated in Government Regulation No. 22 of 2021. The Pollution Index values were calculated by comparing measured parameter concentrations with the applicable water quality standards, following the formulation and classification criteria stipulated in Government Regulation of the Republic of Indonesia No. 22 of 2021.

2.1 Study Area and Sampling Locations

Water quality sampling was conducted at three monitoring points along the Tawangsari River, representing upstream, middle, and downstream segments. The selection of sampling locations was based on differences in surrounding land use and potential pollution sources, particularly domestic activities in residential areas. This approach was intended to capture spatial variations in water quality conditions along the river continuum.

2.2 Water Quality Parameters and Laboratory Analysis

The analyzed water quality parameters included pH, turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). These parameters were selected as they represent key physical and chemical characteristics of river water and are commonly used in pollution assessment studies. Laboratory analyses were conducted in accordance with standard analytical procedures to ensure data reliability and consistency.

2.3 Pollution Index Calculation

The water quality status of the Tawangsari River was determined using the Pollution Index (PI) method in accordance with Government Regulation of the Republic of Indonesia No. 22 of 2021. The Pollution Index value was calculated by comparing the measured concentration of each water quality parameter with its corresponding water quality standard.

The Pollution Index (PI) is calculated using the following equation:

$$PI = \sqrt{\frac{(C_i/L_i)^2_{\max} + (C_i/L_i)^2_{\text{avg}}}{2}}$$

where:

C_i = measured concentration of parameter *i*
L_i = permissible concentration of parameter *i* according to water quality standards
$(C_i/L_i)_{\max}$ = maximum value of the ratio between measured concentration and standard
$(C_i/L_i)_{\text{avg}}$ = average value of the ratio between measured concentration and standard

Based on the calculated Pollution Index values, the water quality status was classified into pollution categories ranging from lightly polluted to moderately polluted, following the classification criteria stipulated in Government Regulation No. 22 of 2021.

2.4 Data Interpretation

The calculated Pollution Index values were used to evaluate spatial differences in water quality among the monitoring points. Emphasis was placed on identifying dominant parameters that contributed to higher Pollution Index values and interpreting their implications for river water quality management. The results were further discussed in relation to surrounding land use characteristics and previous studies to provide a comprehensive understanding of the observed pollution patterns.

3. Results and Discussion

The measurement results of water quality parameters show variations among the monitoring points. Several parameters, particularly dissolved oxygen, exhibit variations among monitoring points, indicating increasing pollution pressure along the river flow. These conditions indicate an increasing pollution load along the river flow, likely influenced by domestic and environmental activities in the surrounding areas.

3.1 Key Water Quality Parameters Influencing the Pollution Index

The key water quality parameters used in the Pollution Index calculation are summarized in **Table 1**. These parameters include pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO), which are commonly used to represent the chemical and biological condition of river water.

Table 1. Summary of Key Water Quality Parameters Used in Pollution Index Calculation

Monitoring Point	pH	BOD (mg/L)	COD (mg/L)	DO (mg/L)
Point 1	7.37	< 2	< 10	3.44
Point 2	7.48	< 2	< 10	3.86
Point 3	7.47	< 2	< 10	4.29
Quality Standard*	6–9	2	10	4

*Quality standard based on Government Regulation of Indonesia No. 22 of 2021 (Class I water).

As shown in **Table 1**, pH values at all monitoring points range from 7.37 to 7.48, indicating neutral conditions and remaining within the acceptable range for Class I water quality standards. This suggests that acidity is not a limiting factor affecting water quality at the study sites. Similarly, BOD

and COD concentrations at all monitoring points are below the respective quality standards, indicating relatively low levels of organic pollution and limited input of biodegradable organic matter.

However, the DO concentrations exhibit a different pattern. At Monitoring Points 1 and 2, DO values are slightly below the minimum standard for Class I water, indicating reduced oxygen availability in the river. This condition may be associated with organic matter decomposition and limited reaeration capacity, particularly in river segments influenced by domestic activities. In contrast, the DO concentration at Monitoring Point 3 exceeds the quality standard, suggesting better oxygen conditions downstream.

The observed variation in DO levels plays a significant role in influencing the Pollution Index values and highlights the importance of dissolved oxygen as a sensitive indicator of river health.

3.2 Pollution Index and Water Quality Status

The Pollution Index (PI) values were calculated to assess the overall water quality status of the Tawangsari River at each monitoring point. The PI calculation was performed by comparing the measured concentrations of water quality parameters with the applicable water quality standards, providing an integrated evaluation of pollution levels.

Table 2. Summary of Pollution Index and Water Quality Status of the Tawangsari River

Monitoring Point	Pollution Index (PI)	Water Quality Category
Point 1	2.245	Lightly Polluted
Point 2	6.439	Moderately Polluted
Point 3	5.106	Moderately Polluted

As shown in Table 2, the Pollution Index values of the Tawangsari River range from 2.245 to 6.439. Monitoring Point 1 exhibits a PI value of 2.245 and is classified as lightly polluted, while Monitoring Points 2 and 3 show PI values of 6.439 and 5.106, respectively, which fall into the moderately polluted category. These differences indicate spatial variation in pollution pressure along the river, with higher pollution levels observed in the middle and downstream segments.

3.3 Spatial Variation of Pollution Index Values

The spatial variation of Pollution Index values along the Tawangsari River was analyzed to identify changes in pollution levels from upstream to downstream sections. This analysis provides insight into the distribution of pollution loads and their relationship with surrounding land-use activities.

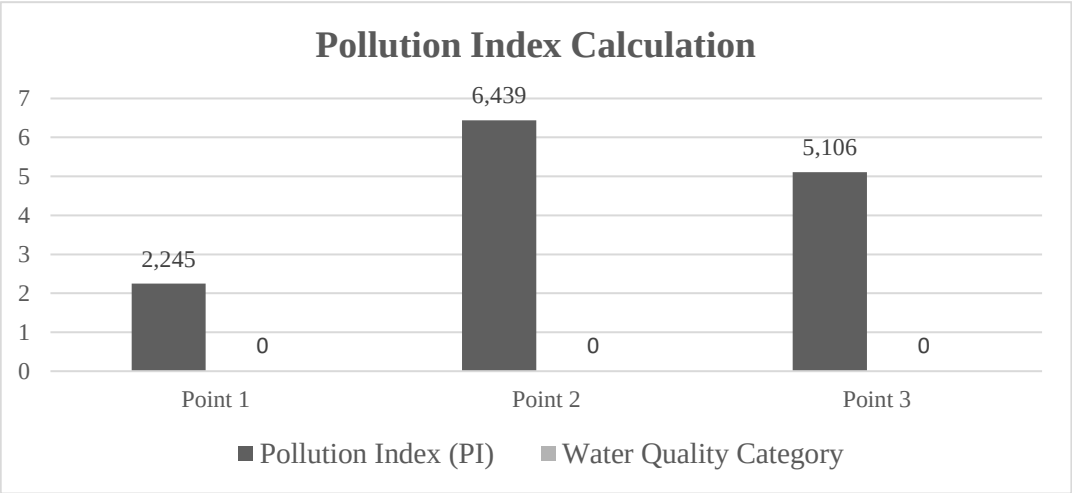

Figure 1. Pollution Index values at each monitoring point

Figure 1 illustrates that the highest Pollution Index value occurs at Monitoring Point 2, representing the middle segment of the river. This condition suggests an increase in anthropogenic pressure, which is likely influenced by domestic activities in surrounding residential areas. Although Monitoring Point 3 remains classified as moderately polluted, the slightly lower PI value compared to Point 2 may indicate the influence of dilution or natural self-purification processes along the river flow. This spatial pattern highlights the importance of controlling pollution sources in the middle segment of the river to effectively manage overall water quality.

3.4 Relationship Between Key Parameters and Pollution Index Values

The relationship between the key water quality parameters and the calculated Pollution Index values is evident when comparing **Table 1** with the Pollution Index results presented in **Table 2**. Although most parameters meet the quality standards, deviations in DO concentrations contribute to the increased Pollution Index values at certain monitoring points.

Monitoring Point 2 exhibits the highest Pollution Index value, which corresponds to lower DO concentrations and increased anthropogenic pressure in the middle segment of the river. This finding indicates that even when organic pollution indicators such as BOD and COD remain within permissible limits, reductions in dissolved oxygen can significantly influence the overall pollution status.

These results demonstrate that the Pollution Index method effectively integrates multiple parameters and is sensitive to changes in key indicators such as DO. Consequently, maintaining adequate dissolved oxygen levels should be considered a priority in river water quality management strategies for the Tawangsari River.

3.5 Dominant Parameters and Management Implications

Although several water quality parameters comply with the applicable standards, the Pollution Index results indicate that certain parameters play a more dominant role in determining the overall water quality status of the Tawangsari River. Among the evaluated parameters, dissolved oxygen (DO) emerges as the most influential factor affecting the Pollution Index values at the monitoring points.

The DO concentrations at Monitoring Points 1 and 2 are slightly below the minimum standard for Class I water quality, while other parameters such as pH, BOD, and COD remain within permissible limits. This condition suggests that even minor deviations in dissolved oxygen levels can significantly influence the Pollution Index classification. Reduced DO concentrations are commonly associated with organic matter decomposition and limited reaeration capacity, particularly in river segments influenced by domestic activities.

The highest Pollution Index value observed at Monitoring Point 2 further supports the role of DO as a dominant parameter. The middle segment of the river is likely subjected to higher anthropogenic pressure due to surrounding residential activities, which may increase oxygen demand and reduce dissolved oxygen availability. In contrast, the slightly lower Pollution Index value at Monitoring Point 3 indicates the potential influence of dilution effects or natural self-purification processes along the downstream section.

From a water resource management perspective, these findings highlight the importance of prioritizing dissolved oxygen as a key indicator in river water quality monitoring programs. Pollution control efforts should focus on reducing organic inputs and improving wastewater management in the middle segment of the river to prevent further degradation. Regular monitoring of dissolved oxygen levels can provide an early indication of declining water quality and support timely management interventions.

3.6 Comparison with Previous Studies

The findings of this study are consistent with several previous studies that have applied the Pollution Index method to assess river water quality in Indonesia. The classification of the Tawangsari River as lightly to moderately polluted aligns with the results reported by Priyono et al., who identified

similar pollution levels in the Surabaya River, primarily influenced by domestic activities and urban land use.

Effendi et al. reported that dissolved oxygen is often a critical parameter influencing pollution index values in rivers subjected to anthropogenic pressure. This observation is in agreement with the present study, where dissolved oxygen emerged as the dominant parameter affecting the Pollution Index values, particularly at the middle segment of the river. Reduced dissolved oxygen concentrations, despite relatively low BOD and COD levels, indicate that oxygen availability can be a sensitive indicator of early-stage water quality degradation.

Similar spatial patterns have also been observed in other river systems. Rosarian et al. documented variations in water quality associated with differences in land use along river segments, where areas with higher residential activity exhibited greater pollution pressure. In the present study, the highest Pollution Index value was recorded at the middle segment of the Tawangsari River, suggesting that land-use intensity plays an important role in determining river water quality.

Overall, the comparison indicates that the water quality characteristics of the Tawangsari River follow a general pattern commonly observed in small to medium-scale rivers in Indonesia. These similarities support the applicability of the Pollution Index method as an effective tool for evaluating river water quality and highlight the relevance of the present findings within the broader context of river water quality studies.

Study Limitations

This study has several limitations that should be considered when interpreting the results. First, water quality sampling was conducted at a limited number of monitoring points, which may not fully capture the spatial variability of water quality conditions along the entire river system. Second, the sampling was carried out during a single observation period, and therefore temporal variations related to seasonal changes were not evaluated.

In addition, the analysis focused on selected key water quality parameters used in the Pollution Index calculation. While these parameters are sufficient to assess overall water quality status, other parameters such as nutrients and microbiological indicators were not included and may provide additional insight into river health. Despite these limitations, the results of this study provide a reliable overview of the water quality status of the Tawangsari River and can serve as a baseline for future monitoring and more comprehensive assessments.

4. Conclusion

The assessment of the Tawangsari River using the Pollution Index method indicates that the river water quality ranges from lightly polluted to moderately polluted. The highest Pollution Index value was observed at the middle segment of the river, suggesting increased anthropogenic pressure associated with surrounding residential activities. Among the evaluated parameters, dissolved oxygen emerged as the dominant factor influencing the Pollution Index values, highlighting its importance as a sensitive indicator of river water quality degradation.

Although most physicochemical parameters complied with the applicable water quality standards, reduced dissolved oxygen concentrations at certain monitoring points contributed significantly to the overall pollution status. This finding emphasizes the need to prioritize dissolved oxygen in routine river water quality monitoring and pollution control strategies.

It should be noted that this study was conducted using a limited number of monitoring points and within a single observation period. Consequently, temporal variations and broader spatial dynamics of water quality were not fully captured. Furthermore, the analysis focused on selected key parameters included in the Pollution Index calculation, while other indicators such as nutrients and microbiological parameters were not evaluated.

Despite these limitations, the results provide a reliable overview of the current water quality status of the Tawangsari River and demonstrate the applicability of the Pollution Index method for small to medium-scale river assessments. The findings provide a baseline reference for future studies incorporating broader spatial coverage, seasonal monitoring, and additional water quality parameters.

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