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JURNAL ILMU LINGKUNGAN
Volume 23 Issue 4 (2025) : 1046-1055 ISSN 1829-8907

Assessing Health Status of Gajahwong River Ecosystem in Yogyakarta City through Biomonitoring and Community Empowerment

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ABSTRAK

Penelitian mengenai penilaian kesehatan sungai dengan biomonitoring yang melibatkan penguatan masyarakat dalam bentuk *citizen science* belum banyak dilakukan. Sehingga penelitian ini bertujuan untuk menilai kesehatan sungai dengan indikator biologi dan melakukan penguatan dalam bentuk keterlibatan masyarakat pada pengambilan dan analisis data. Sungai yang dikaji adalah di Sungai Gajahwong, Kota Yogyakarta yang merupakan sungai di wilayah perkotaan dan mengalami perubahan karena adanya urbanisasi. Metode yang digunakan adalah penilaian kesehatan sungai berbasis biomonitoring makroinvertebrata, penghitungan indeks keragaman, dan secara kualitatif menilai *Citizen Index of Ecological Integrity* (CIEI). Selain itu dilakukan analisis terhadap data kualitas air yang diperoleh dari DLH untuk menjadi pembanding terhadap data yang diambil oleh masyarakat. Hasil penelitian secara umum menunjukan bahwa penilaian indeks bioilik berada pada kategori tercemar sedang, hal ini sesuai dengan hasil pengukuran parameter abiotik (nitrat dan fosfat) yang juga berada pada status tercemar. Sementara itu, indeks CIEI menunjukkan persepsi masyarakat pada kondisi ekologis sungai Gajahwong, yakni berada pada kondisi moderat.

***Kata kunci*:** Assesmen, Biomonitoring, Citizen science, Ekosistem Kesehatan sungai,

ABSTRACT

Research on river health assessment using biomonitoring with community empowerment through citizen science remains limited. This study aims to evaluate river health using biological indicators while fostering community involvement in data collection and analysis. The study focuses on the Gajahwong River in Yogyakarta City, an urban river undergoing changes due to urbanization. The methodology includes river health assessment based on macroinvertebrate biomonitoring, diversity index calculations, and a qualitative evaluation of the Citizen Index of Ecological Integrity (CIEI). Additionally, water quality data from the Environmental Agency (DLH) were analyzed as a comparison to community-collected data. Overall, the results indicate that the biological index falls under the moderately polluted category, consistent with abiotic parameter measurements (nitrate and phosphate), which also indicate pollution. Meanwhile, the CIEI reflects the community's perception of the ecological condition of the Gajahwong River, classifying it as moderate.

***Keywords*:** Assessment, Biomonitoring, Citizen Science, Ecosystem, River health

Citation: Sulistiyowati, E. dan Awaliyah, D. F. (2025). Assessing Health Status of River Ecosystem in Yogyakarta City through Biomonitoring and Community Empowerment. Jurnal Ilmu Lingkungan, 23(4), 1046-1055, doi:10.14710/jil.23.4.1046-1055

1. INTRODUCTION

Biological monitoring (Biomonitoring) has been have increasingly been used as effective indicators of environmental health (Burga and Kratochwil, 2001; Woodward et al., 2013). Biomonitoring has been widely accepted to measure environmental quality and pollutant detections. It can be used to assess various ecosystem, such as the air (Batzias and Siontorou, 2006; Chaudhuri and Roy, 2023), stream and river (Sripanya et al., 2023), and marine environment (Romero-Murillo et al., 2023). The basic principle of biomonitoring is that the presence or absence of specific species or species communities at a given location reflects the overall environmental quality of a certain site (Cairns and Pratt, 1993).

In this study, the term biomonitoring refers to the use of the Biotilic Index, which is based on macroinvertebrate communities. Benthic macroinvertebrates have been employed in biomonitoring studies since the early 1900s (Cairns and Pratt, 1993; Resh and Jackson, 1993). The use of macroinvertebrates as bioindicators offers several advantages, such as ease of application and the lack of need for complex equipment (Morse et al., 2007).

Moreover, macroinvertebrate communities are naturally sensitive to environmental changes, making them effective in reflecting ecological conditions in the presence of pollutants (Kahirun et al., 2023).

In Indonesia, the application of benthic macroinvertbrates as bioindicators remains relatively limited to academic settings, particularly following the publication of macroinvertebrate monitoring guidelines by Rini (2011). Some of the studies that have employed the methods developed by Rini et al. (2011), including the river assessments in Sidoarjo (Anastasia et al., 2022), in a tributary of the Brantas River (Wardhani and Prijono, 2025), and in the Boyong River, Yogyakarta (Sulistiyowati et al., 2024).

As a transformative approach to modern resource management, biomonitoring has received substantial research investment. However, despite its global recognition, the application of biomonitoring has been limited in Indonesia. An inadequate policy framework has hindered the adoption of biomonitoring as an official tool for environmental quality assessment.

For river water quality monitoring, the Indonesian government has adopted a range of physical, chemical, and biological parameters, as outlined in Law No. 22 of 2021 on the Administration of Environmental Protection and Management. Although this regulation provides guidelines for water quality standards, the parameters it examines are technical and require laboratory testing, making them inaccessible to the public. In addition, the parameters only focus on the water, not the status of river health in general. As a result, the regulation fails to reach the diverse levels of public knowledge. Furthermore, it does not effectively foster public awareness or participation in water quality management.

The current government approach only focuses on physicochemical indicators predominantly emphasizes physicochemical parameters requiring laboratory-based analyses, thereby constraining public accessibility and engagement. The integration of bioindicators as official criteria within national regulatory frameworks presents challenges across multiple countries, extending beyond the context of Indonesia. In regions such as Africa, South-Central America, Mexico, and Southern Asia, despite substantial research efforts, the application of bioindicators for water quality assessment remains largely absent from formal national legislation. (Eriksen et al., 2021). Some countries only use a citizen science approach regionally to conduct biomonitoring, such as Southern Africa, Gambia, East Africa, Brazil, Canada (Feio et al., 2021). Even China, which has had the Guidelines for Aquatic Ecological Protection and Restoration Planning in 2015, has not conducted biomonitoring on a national scale (Feio et al., 2021), although there has been research on a national scale (Dong et al., 2023; Li et al., 2023)

Seeing the difficulty of using bioindicators in the national framework for water quality measurement, it appears that there is a lack of an integrative and participatory biomonitoring framework. This is the main urgency in this study because there is a critical gap in assessing river quality using bioindicators.

To answer this urgency, this research uses citizen science that can increase public participation. A key approach to enhancing public engagement in water quality monitoring and river health assessment is the use of participatory methods and citizen science as strategies for community empowerment. Research on this topic has started to grow. For example, Sulistiyowati and Uyun (2024) have developed a web-based biomonitoring system designed to increase community involvement in monitoring Gajahwong River health, and Thatoe Nwe Win et al (2019) who developed an affordable method for participatory monitoring the Ayerwadi River in Myanmar.

These studies are grounded in the principle that citizen science and participatory approaches offer several advantages, such as cost-effectiveness (Thatoe Nwe Win et al., 2019), participatory engagement and increased community involvement (Rodriguez, 2023), and thus this method promote community empowerment. Community empowerment through citizen science is important because local community usually holds strong traditional knowledge about their ecosystem. However, there are aspects that require further investigation regarding the use of citizen science in river health biomonitoring, such as the accuracy and alignment of conclusions drawn from participatory monitoring by the public compared to data published by authorities. Additionally, the socio-cultural aspects of the community must also be considered (Aura et al., 2021).

Although this study develops from Sulistiyowati and Uyun (2024), the current study advances the work by incorporating comparative analysis between official data and community-collected data, applying biotic indices and the Citizen Index of Ecological Integrity (CIEI) to provide a multi-dimensional view of river health. This study also evaluates the effectiveness of community science in detecting ecological degradation and offers a quantitative assessment of community empowerment as a novel contribution.

In this study, we assess the river health status of the Gajahwong River in Yogyakarta. The Gajahwong River is one of the three major urban rivers in Yogyakarta City and is considered representative of the overall ecological status of urban rivers in the area due to its significant exposure to rapid urbanization, domestic wastewater, and industrial activities. (Widagda et al., 2021). These pressures are similar to those affecting the Code and Winongo Rivers (Indrastuti et al., 2023), making Gajahwong a suitable case study to represent broader urban river health challenges in Yogyakarta.

Thus, the study has two main objectives: first, to evaluate river health quality using a biomonitoring method, with data collected through participatory monitoring, and compare these results with pollution index values measured by relevant authorities.

Second, we measure the community empowerment through the citizen index of ecological integrity (CIEI) to gain a broader understanding of the river's condition from the community's perspective.

2. METHODS

2.1. Study Area

Gajahwong is one of the three major rivers flowing through Yogyakarta, Indonesia. It is a sub-watershed of the Opak River Basin, which includes the Winongo and Code rivers. The river has a total length of 32 km and spans an area of 65.5 km^2, draining parts of Sleman Regency, Yogyakarta City, and Bantul Regency (Figure 1).

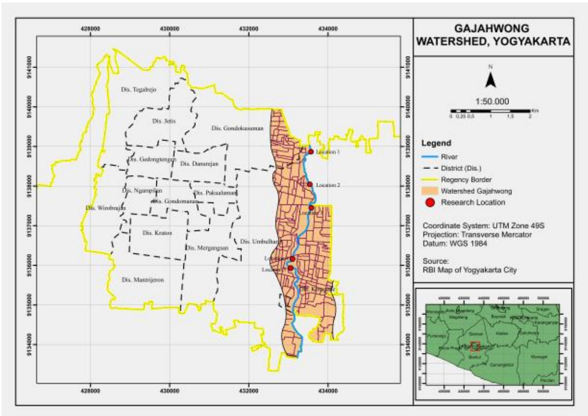

Figure 1. Map of Gajahwong River Showing Five Locations of the Study, Including (1) Santo Tomas, (2) Balirejo, (3) Gembira Loka, (4) Logatak, (5) Tegal Gendu

The Gajah Wong River is classified into two water quality categories based on Peraturan Gubernur Daerah Istimewa Yogyakarta No. 22/2007: Class I in the upper reaches (used as a raw water source for drinking, requiring treatment) and Class II in the middle and lower reaches (suitable for recreational, agricultural, and aquaculture uses). However, the river faces significant pollution challenges, primarily from domestic, industrial, and agricultural waste (Widagda et al., 2021).

2.2. Participants

Participants were selected from youth groups and university students actively involved in environmental monitoring. These groups included the Water Forum, Yayasan Yandara, KSE, and KS Botani from UIN Sunan Kalijaga. A total of 31 participants took part in the river quality monitoring conducted in this study. The monitoring process was guided by researchers and biomonitoring experts from the Water Forum.

Youth and students were chosen due to their growing involvement in environmental activism in Yogyakarta, as seen in local river conservation movements (Ulfah et al., 2020). Engaging youth promotes long-term behavioral change and sustainability of river conservation efforts. The Gajahwong River area is surrounded by educational institutions and residential areas for students, which makes youth involvement contextually relevant for promoting stewardship and embedding environmental values early (Teixeira et al., 2021).

In contextualizing the citizen science model locally, the socio-cultural characteristics of Yogyakarta youth play a pivotal role. As a city renowned for its vibrant student population and strong cultural identity, Yogyakarta fosters a community of young people who are generally well-educated, socially engaged, and increasingly conscious of environmental issues. The widespread presence of youth-led environmental and social organizations in the region underscores the feasibility of participatory research models. As a comparison, Yogyakarta has 21 environmental youth organizations, which is the highest number compared to other provinces (Nugroho, 2017, 2018). Moreover, according to data from the Yogyakarta City Statistics Agency (BPS Kota Yogyakarta, 2022) based on the 2020 Population Census and updated in 2022, the youth population in Yogyakarta is considerable. The number of individuals aged 15–19 years is recorded at 29,925, those aged 20–24 years at 33,489, and those aged 25–29 years at 29,601. This brings the total number of youth aged 15–29 years to approximately 93,015 individuals. This demographic constitutes a significant portion of the city's population and represents a vital group for mobilization in environmental and community-based initiatives, including citizen science programs.

These socio-cultural traits significantly enhance both the motivation and capacity of youth to actively participate in scientific activities, particularly in environmental monitoring and advocacy.

2.3. Official Water Quality Data

The water quality data were sourced from the Information on Regional Environmental Management Performance report for 2023, published in 2024 (BLH Kota Yogyakarta, 2024). This data, provided by the Yogyakarta City government, will serve as a reference for comparing the river health assessments conducted through community-based biomonitoring. The Yogyakarta City BLH monitors eight physical and chemical parameters, which include microbiological indicators (fecal coliform and total coliform), inorganic chemicals (sulfide/H_2S and free chlorine/Cl_2), and nutrient compounds (total phosphate as P, nitrite as N, and ammonia). Additionally, other pollutants identified in the Gajahwong River water samples, though not classified as primary contaminants, include organic chemical compounds such as BOD, detergents, phenols, and COD.

The official water data was obtained from the Environmental Agency (BLH). The data were analyzed to determine the river's health status using the pollution index. The pollution index method is calculated according to the Minister of Environment Decree No. 115/2003, Annex II, regarding the determination of water quality status, with the pollution index formula (1).

$$Pi = \sqrt{\frac{\frac{(Ci)}{(Lij)}^2 M \, X \, \frac{(Ci)}{(Lij)}^2 R}{2}} \qquad (1)$$

Pi : Pollution index
Ci = Concentration of water quality parameter i
Lij = Concentration of water quality parameter i specified in the water quality standard for allocation j
M = Maximum
R = Average

The pollution index formula (1) calculates water quality status by comparing measured pollutant concentrations to regulatory standards. The pollution index classes (PI) are as follows:
Score 0 ≤ Pij ≤ 1.0: Good
Score 1.0 < Pij ≤ 5.0: Slightly polluted
Score 5.0 < Pij ≤ 10.0: Moderately polluted
Score Pij > 10.0: Heavily polluted

2.4. Data Collected by the Community

This study focuses on community capacity building for river health monitoring. Although the activity relies on community involvement, this research strives to ensure that scientific rigor is maintained. Therefore, training on river health monitoring is conducted with expert guidance and the use of field equipment that meets scientific standards, provided by the Ecology Laboratory of UIN Sunan Kalijaga.

Data collection was conducted on two occasions, in September 2023 and September 2024; however, only the data from September 2023 was utilized for comparison with the official data provided by the relevant authorities. The data collection procedure followed the method described by Rini (2011) in the book *Ayo Cintai Sungai*. According to these guidelines, the biomonitoring approach employed involved the use of macroinvertebrate communities, referred to as Biotilik.

Table 1. Taxon Group and the Biotilik Score

Group (Category)	Taxon/family	*Biotilik* score
A (Very sensitive)	Tanyderidae, Philopotamidae, Gompidae, Nemouridae, Perlidae	4
B (Sensitive)	Baetidae, Gyrinidae, Saldidae, Tipulidae, Naucoridae, Palaemonidae, Scirtidae,	3
C (Tolerant)	Gerridae, Lymnaeidae, Chironomidae, Caenidae, Buccinidae, Simulidae, Parathelpusidae, Thiaridae	2
D (Very tolerant)	Tubificidae Hirudinae, Lumbricidae, Glossophonidae	1

The index is calculated by multiplying the abundance of each species (ti) by its corresponding biotic score (ni), which reflects the sensitivity of each taxonomic group to environmental pollution. Taxonomic groups are categorized based on their tolerance or vulnerability to pollution, hence the index can provide a weighted measure of biodiversity that accounts for both species richness and the ecological quality of the habitat. The biotilik index (formula 2) calculates a score by summing the weighted presence of indicator taxa, where a higher biotilik score reflects better ecological conditions and cleaner water quality.

$$Bi = number\ of\ spesies\ (ti)\ X\ biotilik\ score\ (ni) \quad (2)$$

Table 1 presents the specific biotilik scores assigned to each taxon used in the biomonitoring process.

The biotilik score could be translated as follows (Table 2).

Table 2. The *Biotilik* Index Category to River Health

Biotilik Index	Category of River Health/Quality
3.1 - 4.0	Very clean, very light pollution
2.6 - 3.0	Clean, slightly polluted
2.1 - 2.5	Slightly polluted, moderate pollution
1.6 - 2.0	Dirty, rather heavy pollution
1 - 1.5	Very dirty, heavy pollution

In addition to the biotilik index, biomonitoring was also conducted to assess biodiversity abundance using the Shannon-Wiener index (H'), as follows:
H'= -Σ Pi ln (Pi), where Pi = (ni/N)
H'= Shannon-Wiener diversity index
ni = number of individuals of species i
N = The number of individuals of all species
The qualitative criteria for the diversity index's score:
H' < 1: low diversity
1< H' ≤3: moderate diversity
H'> 3: high diversity

2.5. Citizen Index of Ecological Integrity (CIEI)

CIEI was obtained from the community's assessment of river health criteria. The instrument used to evaluate CIEI was developed and modified from Aura et al. (2021). Aura et al. utilized 16 criteria, whereas this study applied only 12 criteria, as some of the criteria from Aura et al. were considered less relevant to the context of urban rivers in Yogyakarta City. The metrics used in this study are presented in Table 3. Qualitatively, the CIEI scores are interpreted as follows:

Score >40 : Good water quality; slight pollution characteristics and some degradation. No human activity within 50m of the riparian zone, clear water with visible substrate.

Score 20-39 : Moderate water quality; significant pollution levels and degradation. Riparian zone >20m wide with minimal human activity; substrate mainly of coarse and fine material.

Score <19 : Poor water quality; major/heavy pollution and degradation. Riparian zone <20m; collapsed and eroded sites; human activity included agriculture, water abstraction, urbanization and deforestation; bottom dominated by sand and organic materials; water is turbid.

Table 3. The Metrics for Assessing River Health Status are Based on Aura et al. (2021)

Metrics	Score		
	5	3	1
Water color	Colorless	Browngreen	Black
Water odor	No smell	Musty	Pangent
Average number of endemic fish	>10	6-10	<5
Use of river as waste disposal site	<5	4-20	>20
Number of bathing/swimming areas per site	<3	4-5	>5
Number of industries per site	0	1-2	>2
Number of farmlands per site	<10	11-29	>30
Number of urban areas per site	<1	2-3	>3
Number of settlements per site	<1	2-3	>3
Number of conservation groups	>2	1	0
Number of site with cultural rites	>2	1	0
Number of roads/transport network	<1	2-3	>4

3. RESULT AND DISCUSSION

3.1. Water Quality Data

Water quality data derived from the Environmental Agency consist of biological, chemical, dan physical parameter.

a. Biological Parameter

The biological parameters reported in the official data are fecal coliform and total coliform (Figure 2 and Figure 3).

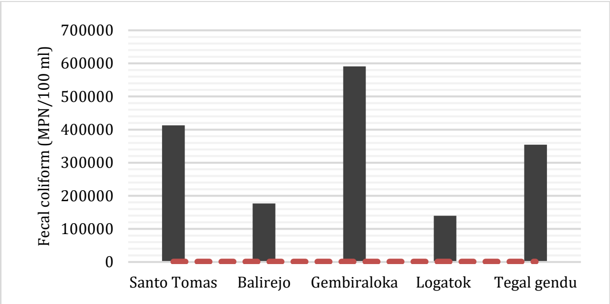

Figure 2. Concentration of Fecal Coliform (MPN/100ml) in the Gajahwong River

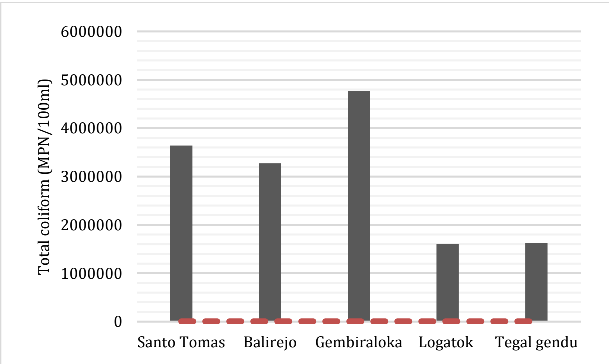

Figure 3. Concentration of Total Coliform (MPN/100ml) in the Gajahwong River

Based on Figures 2 and 3, both biological parameters measured have exceeded the established quality standards in all samples from all tested locations (100%). It can be concluded that the Gajahwong River water is contaminated with fecal coliform and total coliform.

Regarding microbial pollution, several previous studies have reported that water in the Gajahwong Watershed (DAS) has been contaminated. Some studies have confirmed this contamination, for example, Winata and Hartantyo (2013), who showed that microbial contamination had already occurred in the groundwater within the watershed. Another study by Hendrayana et al. (2023) also reported coliform contamination with concentrations exceeding the quality standards set by the World Health Organization (WHO).

b. Chemical Parameter

The Environmental Agency presents diverse data on physical and chemical parameters, primarily measured through the concentrations of phosphate and nitrate (Figure 4 and Figure 5.) The data indicate variations in chemical concentrations, serving as indicators of river pollution and water quality. Furthermore, the data reveal that the river is experiencing pollution, as evidenced by the presence of chemical substances that exceed the established quality standards.

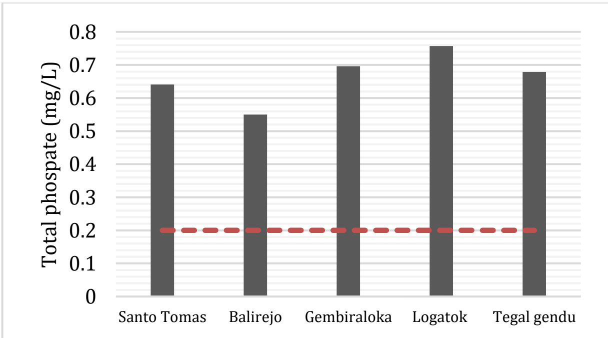

Figure 4. Concentration of Total Phosphate (mg/l) in the Gajahwong River

Several studies have confirmed that, both physically and chemically, the Gajahwong River is indeed contaminated with chemical substances (Ahdiaty and Fitriana, 2020). The data published by the Environmental Agency (DLH) further substantiates the occurrence of pollution in the Gajahwong River, primarily attributed to phosphate and nitrate sources, which are suspected to originate from domestic waste pollution.

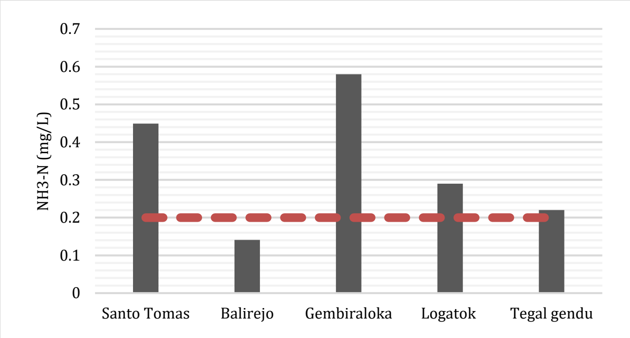

Figure 5. Concentration of Total NH3-N (mg/l) in the Gajahwong River

3.2. Community Data on Biomonitoring

The community was directly involved in data collection as part of the implementation of empowerment and community science. The data were collected with the guidance of expert teams recruited by the researchers, resulting in macroinvertebrate composition data, which were utilized as biological indicators in biomonitoring (Figure 6).

Figure 6 shows that the majority of families found at the study site belong to non-EPT taxa, while EPT groups were found in very low numbers.

EPT groups are known as pollution-sensitive insects and are typically found only in unpolluted areas. In high-quality waters, studies have shown that a significant number of EPT families can be observed. For instance, 11 EPT families were recorded in the Legundi River, Probolinggo, East Java (Sulastri and Sundari, 2023). Similarly, studies on rivers abroad have demonstrated good river health through the presence of a greater number of EPT families, resulting in higher biomonitoring scores (Blakely et al., 2014; Sripanya et al., 2023). Researchers have linked macroinvertebrate diversity to the presence of riparian vegetation. Bohus et al. (2023) highlighted shifts in macroinvertebrate composition due to physical alterations in riparian vegetation and abiotic river factors caused by urbanization. This phenomenon can also be observed in the Gajahwong River, an urban river undergoing significant changes due to urban settlement.

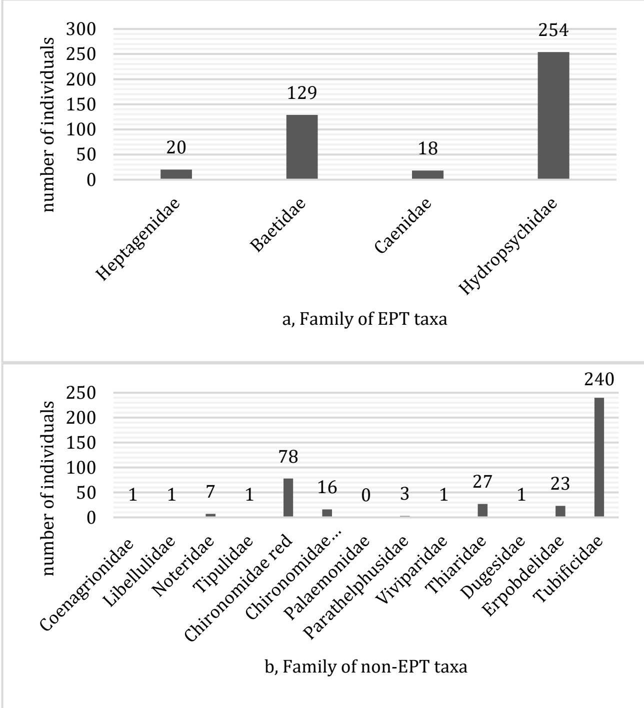

Figure 6. The Diversity of Macroinvertebrate Families Includes (a) EPT Taxa and (b) Non-EPT Taxa

3.3. Citizen Index of Ecological Integrity (CIEI)

The CIEI measures the social and ecological attributes of an ecosystem from the community's perspective. The CIEI used in this study is a modification of the framework proposed by Aura et al. (2021). The results of the CIEI measurements are as follows in Table 4.

The CIEI scores reveal variations in ecological and social attributes across the five locations. Water quality indicators, such as color and odor, consistently scored 3, indicating moderate conditions, while the average number of endemic fish scored uniformly low (1), reflecting limited biodiversity. Locations with higher industrial activity, such as 2 and 5, and greater river use for waste disposal, particularly Location 1, showed higher human impact. Conversely, farmlands, urban areas, and settlements had minimal influence, as these metrics consistently scored low across all sites.

Table 4. Citizen Index of Ecological Integrity

Metrics	CIEI score in each location				
	Location 1	Location 2	Location 3	Location 4	Location 5
Water color	3	3	3	3	3
Water odor	3	3	3	3	3
Average number of endemic fish	1	1	1	1	1
Use of river as waste disposal site	5	3	3	1	1
Number of bathing/swimming areas per site	1	1	1	1	1
Number of industries per site	1	3	1	1	3
Number of farmlands per site	1	1	1	1	1
Number of urban areas per site	1	1	1	1	1
Number of settlements per site	1	1	1	1	1
Number of conservation groups	1	1	1	3	1
Number of site with cultural rites	1	1	1	1	1
Number of roads/transport network	5	1	1	1	1
Total	24	20	18	18	18
Qualitative criteria	moderate	Moderate	Poor	Poor	poor

Overall, Locations 1 and 2 were classified as "moderate" in ecosystem health, while Locations 3, 4, and 5 were categorized as "poor". The higher presence of conservation groups in Location 4 and more developed infrastructure in Location 1 were notable exceptions, contributing to localized variations. These findings underscore the impact of human activities and the need for biodiversity and conservation efforts to improve ecosystem health across all locations.

3.4. Comparison of Official Data dan Community Science

The river health assessment across five locations reveals variations in pollution levels and biodiversity. Based on the Pollution Index, all locations are categorized as moderately polluted, with Santo Tomas showing the highest index (9.39) and Balirejo the lowest (7.6). The Biotic Index indicates varied pollution levels, from "slightly polluted" in Balirejo and Tegal Gendu to "very dirty, heavily polluted" in Gembira Loka. Shannon-Wiener Index values were consistently low across all sites (1.11–1.61), highlighting uniformly low biodiversity, with Santo Tomas showing slightly higher diversity (H' = 1.61).

The CIEI classifies Santo Tomas and Balirejo as having "moderate" ecological integrity (scores of 24 and 20, respectively), while Gembiraloka, Logatok, and Tegal Gendu are categorized as "poor" (scores of 18). These findings emphasize that, despite moderate pollution levels, low biodiversity and poor ecological integrity prevail, suggesting that anthropogenic pressures significantly impact river health. Conservation efforts are to enhance biodiversity and reduce pollution across these locations.

When compared to water quality data collected by authorities and citizen science, there are noticeable differences. The distinction lies in the fact that data from authorities are more specific, referring to particular chemical and physical parameters, with pollution indices derived from the aggregation of these data. The official data (PI) is derived solely from physicochemical parameters (e.g., nitrate, phosphate, BOD, coliform) using a standard regulation according to the Ministerial Decree No. 115/2003. These measurements are typically collected at regular intervals and then averaged across different sampling locations. The classification of water quality is determined by comparing these averaged concentrations with the reference value specified in the standard. However, because the PI relies on an aggregated formula, variations between individual sites may become less apparent. Consequently, areas with differing pollution characteristics have the same classification—for instance, "moderately polluted." This outcome is especially common in urban river settings, where pollution sources are locally dependent (Yang et al., 2021) and baseline contamination levels tend to be uniformly high. Research shows that baseline pollution of various pollutants in urban areas tends to be high, for example the baseline of heavy metal pollution in urban areas in Polandia (Wojciechowska et al., 2019) and China (Wu et al., 2025).

In contrast, citizen science data are based on macroinvertebrate monitoring and the CIEI, which tend to be more qualitative. However, both methods of water quality assessment complement each other in describing the condition of the Gajahwong River. For instance, when laboratory data show that fecal coliform, total coliform, phosphate, and nitrate levels exceed the threshold limits, the biotic index simultaneously indicates pollution, ranging from light to rather heavy levels (Table 5).

CIEI captures not only environmental indicators (e.g., water color, odor, endemic species presence) but also social and cultural attributes (e.g., waste dumping, conservation efforts, nearby cultural activity) . These indicators are observed and scored directly at the local scale, allowing finer spatial differentiation in ecological perception. For example, two locations may have similar nitrate levels (and thus identical PI scores), but may differ significantly in visible degradation (e.g., number of conservation groups, settlement pressure), leading to different CIEI outcomes.

Furthermore, CIEI integrates community-based qualitative knowledge, which often reflects real-time, cumulative experiences of environmental change. This kind of perception-based data can capture subtler ecological stressors or degradation (e.g., habitat fragmentation, sedimentation, cultural disconnection) that are not represented in physicochemical testing. Thus, the reason official scores tend to cluster within one pollution class is due to: Averaging of numerical values across limited parameters, Exclusion of ecological and social dimensions, Less frequent sampling intervals, which may miss episodic pollution events. In addition to being combined with biotilik, CIEI can reportedly be combined with other citizen science-based water quality monitoring methods, such as fish monitoring, diatoms, and phytoplankton (Kitaka et al., 2024).

By combining, PI formula, CIEI approach, and biotilik, the study illustrates the value of multi-source assessment. In this case, PI offers standardized comparability, while CIEI enriches contextual understanding, and biotilik provides local specificity.

Although the use of multi-indices assessment is not yet common in Indonesia, such assessment approaches have been widely studied. For instance, macroinvertebrate-based multimetric indices have been applied in lake ecosystems (Ndatimana et al., 2023). biocriteria for water assessment have been developed in Malaysia (Arman et al., 2019), and multimetric assessments have been designed for Mediterranean ponds (Trigal et al., 2009). These studies indicate a positive trend in the application of multimetric indicators involving macroinvertebrates. However, the integration of such assessments into formal environmental management frameworks remains challenging in various parts of the world (Burga and Kratochwil, 2001; Kitaka et al., 2024).

Table 5. River Health Status of Various Indexes and Data Sources

Location	Pollution Index		Biotic Index		Shanon Wiener Indeks (H')		Citizen ecological Integrity Index	
Santo Tomas	9.39	Moderately polluted	2.6	Slightly polluted	1.61	Low biodiversity	24	Moderate
Balirejo	7.6	Moderately polluted	2.7	Slightly polluted	1.48	Low biodiversity	20	Moderate
Gembiraloka	8.66	Moderately polluted	1.5	Very dirty, heavy pollution	1.11	Low biodiversity	18	Poor
Logatok	7.85	Moderately polluted	1.8	Dirty, rather heavy pollution	1.50	Low biodiversity	18	Poor
Tegal gendu	8.62	Moderately polluted	2.7	Clean, slightly polluted	1.51	Low biodiversity	18	Poor
Source of data	DLH, 2023		Community		Community		Community	

The implementation of macroinvertebrate-based biomonitoring in Indonesia remains limited due to several constraints, including the absence of standardized national protocols, a shortage of taxonomic expertise, and limited institutional support. Current water quality assessments still prioritize physico-chemical parameters, while awareness and capacity among stakeholders remain low. These challenges hinder the integration of biological monitoring into formal river management frameworks.

Many cases demonstrate that citizen science data complement government data. For instance, in Hong Kong, citizen science has been proposed as an alternative approach, serving as part of new integrated water management approach (Ho et al., 2020). In addition, community engagement in water quality data collection can identify pollution hotspots and ecological integrity that are often overlooked by official monitoring (Stankiewicz et al., 2023). In this case, CIEI plays a role in complementing the guidelines regarding ecological integrity and pollution sources that are often not recognized by the relevant authorities.

4. CONCLUSION

This study demonstrates the utility of biomonitoring combined with community empowerment to assess river health in the Gajahwong River, an urban waterway impacted by pollution and urbanization. The results reveal moderate pollution levels based on both biological and chemical indices, with nitrate and phosphate concentrations exceeding established quality standards. The biomonitoring process, conducted with community participation, identified macroinvertebrate diversity dominated by non-EPT taxa, indicating suboptimal ecological conditions.

Additionally, the CIEI reflects the community's perception of the river's ecological health, categorizing it as "moderate." This alignment between community-based and official data highlights the value of citizen science in fostering local engagement and providing complementary insights into river management. Moving forward, integrating community-based monitoring with institutional frameworks is recommended to enhance public participation and implement targeted interventions for urban river conservation.

ACKNOWLEDGMENTS

The researcher would like to express gratitude to the Ministry of Religious Affairs, Republic of Indonesia for the funding support through the Research and Community Service Grant, No. SK 5361/Year 2024. The researcher also extends sincere thanks to all the participants involved in the community science data collection, as well as the trainers, M. Nur Zaman and Imam Syafii.

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