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Original article

Assessing Water Quality and Prioritizing Pollution Control Strategies for Brangkal River, Mojokerto City, Using WQI and AHP Approaches

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Abstract

Brangkal River supports domestic, agricultural, and economic activities in Mojokerto City. At the same time, it is under growing pressure from human activity, and the way pollution is currently controlled is not clearly tied to the river's measured condition. This study analyzes the water quality and pollution status of the Brangkal River and develops pollution control strategies using the Analytic Hierarchy Process (AHP). Water quality index (WQI) was assessed from laboratory-based monitoring data for March and July 2025 by the Environmental Agency of Mojokerto City, which were compared against national water quality standards (IKA). The control strategies were prioritized through the AHP, where four criteria — ecological, social, institutional, and technical — and eight strategic alternatives were evaluated by 10 experts through pairwise comparisons; all comparison matrices returned consistency ratios < 0.1. Based on IKA, the river was classified as moderate, with a mean WQI score of 72.71 across six measurements points. Individual scores ranged from 66.33 to 79.12, and WQI declined in all three segments between March and July 2025. The TSS, BOD, and fecal coliform exceeded the standard limits, which points to organic and nutrient pollution associated mainly with untreated domestic wastewater and surface runoff. The AHP identified the institutional criterion as the most influential (38.83%) and ranked water quality monitoring as the leading strategic alternative (17.01%), followed closely by improving community attitude toward the river (16.58%). These indicate that restoring the Brangkal River depends on an integrated approach and on sustained cooperation among government, communities, and stakeholders.

Keywords: Analytic Hierarchy Process, Brangkal River, Water Pollution Control Strategy, Water Quality Index

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Introduction

The Brangkal River supports community livelihoods in Mojokerto City. It supplies water for domestic activities and contributes to local social welfare. The river runs through the eastern part of the city, and its banks are used for housing, industrial activity, and small and medium enterprise (SME) trade. Population growth and the intensification of activity along the basin have raised pollution loads. As economic areas expand and settlements spread along the banks, the waste they produce degrades river water quality (Dewi et al., 2026). This degradation is not only an environmental problem. It also disrupts local economic stability and the livelihoods that depend on the river. Polluted water reduces access to clean water, and it raises the risk of waterborne diseases such as diarrhea, dysentery, and skin irritation. Health effects of this kind lower labor productivity and add to the socio-economic burden carried by households (Chabib et al., 2025). Within the administrative area of Mojokerto City, the Brangkal River is classified as being of moderate water quality based on the nationally standardized *Indeks Kualitas Air* (IKA).

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Research on the Brangkal River has so far concentrated on microalgae (Hanin et al., 2016) and on heavy metal concentrations (Syafriliansah & Purnomo, 2022). These studies give useful information on specific pollution indicators. They assess water quality on its own, however, and do not connect that assessment to any water pollution control strategy. The consequence of this gap is visible in current local practice. The 2024 work plan of the Mojokerto City Environmental Agency identifies domestic sources — untreated septic tanks, detergents, and household wastewater — as the main contributors to river pollution. Even so, the agency's routine monitoring is concentrated on twenty industrial effluent points, and its stated improvement measures are general ones, such as compliance data collection, public outreach, and guidance for business operators (Environmental Agency of Mojokerto City, 2024). The apparent mismatch is that the diagnosed pollution sources are not the sources that the control effort targets. This mismatch points to a broader problem. When water quality assessment is not linked to the apportionment of pollution among sources, control measures cannot be reliably directed to the sources that contribute most.

Studies that combine water quality assessment with source apportionment further clarified this point. They show that identifying the relative contribution of industrial, domestic, and natural sources gives the integrated basis needed for targeted pollution management and policy formulation (Dewi et al., 2025). The available evidence on the Brangkal River therefore describes the condition of the river. It does not show which interventions deserve priority. Decision-makers are left without a clear analytical basis for action. Research that combines water quality analysis with the design of pollution control strategies for the Brangkal River thus remains scarce. Addressing pollution in the river is necessary to keep its water resources usable over the long term. It also supports Sustainable Development Goal 6, which concerns access to clean water and the sustainable management of water resources.

This study addresses that gap. It evaluates the water quality of the Brangkal River and uses the evaluation to develop pollution control strategies. Water quality is assessed against the national water quality standards and water use classifications set out in Annex VI of Government Regulation No. 22 of 2021 on Environmental Protection and Management (Anggayasti et al., 2024). The concentration of each measured parameter is compared with the applicable standard to check compliance with the designated water quality class. Water quality status is then determined through the Water Quality Index (WQI) formula, which expresses overall water quality as a composite of parameters for a given area and time (Siriwardhana et al., 2023) and classified based on Indonesian's *Indeks Kualitas Air* (IKA) to determine the pollution severity. The qualitative and quantitative data are then analyzed with the Analytic Hierarchy Process (AHP) to develop pollution control strategies that can be applied in practice (Ramdlan & Azmiyati, 2022). AHP is useful here because of pollution sources, institutional constraints, and the social and environmental pressures on the river interact in ways that are difficult to weigh informally. This integrated approach gives the study a firmer analytical basis for river management strategies that are specific, adaptive, and sustainable.

Methods

Research Design

This study uses a mixed methods approach. It combines quantitative and qualitative data to support the formulation of pollution control strategies for the Brangkal River. The quantitative data are used to assess water quality status through the Water Quality Index (WQI). The qualitative data, drawn from interviews and field observations, provides the basis for the Analytic Hierarchy Process (AHP), through which pollution control strategies are weighted and prioritized. This combined approach provides an evidence-based foundation for developing river management strategies that are specific, contextual, and sustainable.

Study Area and Time

This study was conducted in March and July 2025 along the Brangkal River, within the administrative boundaries of Mojokerto City. Water quality data were drawn from three monitoring points that represent the upstream, midstream, and downstream sections of the river. The upstream point was located at KH Usman Bridge in Surodinawan Urban Village (7.48979° S, 112.42455° E). The midstream point was at Tribuana Tunggadewi Bridge, on the border of Prajuritkulon and Miji Urban Villages (7.47892° S, 112.42728° E). The downstream point was at Balongcangkring Bridge in Mentikan Urban Village (7.46642° S, 112.42735° E). Field observations and in-depth interviews were also conducted with key informants from local communities and relevant institutions, to identify the factors that influence pollution in the Brangkal River.

Data Collection

This study uses both secondary and primary data. The secondary data was obtained from the Environmental Agency of Mojokerto City, which conducts routine water quality monitoring of the Brangkal River. The dataset consists of laboratory-based measurements of eight key parameters: pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrate, total phosphate, and fecal coliform, covering the March–July 2025 monitoring period. Each parameter was measured in triplicate by the agency. Other secondary data, including previous research findings, activity reports, and supporting documents, were collected from official government sources and peer-reviewed scientific literature.

The primary data were obtained through direct field observation of river conditions and through interviews on the existing river pollution issues. The interviews followed a semi-structured approach. Respondents were selected through purposive sampling, so that the stakeholders involved would be those with relevant information, direct experience, and institutional roles in river pollution management (Muhaiman et al., 2023; Ahmad & Wilkins, 2025). The semi-structured format allowed the use of predefined guiding questions while still leaving room to explore issues that emerged in the field, and to obtain contextual and governance-related information that cannot be captured through water quality measurements alone (Junnier, 2025). The respondents were drawn from communities living along the riverbanks and from policy-making institutions responsible for water pollution management. This selection supported the identification and prioritization of strategies in the AHP analysis.

Data Analysis

The data analysis followed the order in which the data are described above. The secondary water quality data were analyzed first, and the primary observation and interview data were analyzed afterward.

For water quality analysis, the concentration of each of the eight parameters was compared with the Class II water quality standards specified in Annex VI of Government Regulation No. 22 of 2021 (Anggayasti et al., 2024). Water quality status is defined as an indicator of the condition of a water body and its compliance with established standards over a given period (Pongoh et al., 2021). This status was determined using the Water Quality Index (WQI), which is referred to in the Indonesian regulatory framework as the *Indeks Kualitas Air* (IKA) and was calculated following the Regulation of the Ministry of Environment No. 14 (Ministry of Environment, 2025). Each observed parameter value was first transformed into a dimensionless sub-index value (Qi) using the parameter-specific sub-index equations provided in the regulation. The WQI/IKA score was then calculated as the weighted sum of the eight sub-index values.

$$WQI = IKA = \sum_{i=1}^{8} w_i Q_i$$

where:
i = the i-th parameter
8 = the total number of parameters used
wi = the weighting factor of the i-th parameter
Qi = the sub-index value of the i-th parameter

The weighting factors are predetermined values established in the regulation; they are not weights estimated from the study data, and they were therefore taken directly from the regulatory table (Table 1). The resulting IKA score was classified into three categories: very good (85 < x ≤ 100), moderate (60 < x ≤ 85), and poor (0 ≤ x ≤ 60).

Table 1. Weighting factors for water quality parameters in the WQI/IKA calculation (Regulation of the Minister of Environment No. 14 of 2025)

Parameter	Weight (wi)
pH	0.137
BOD	0.132
COD	0.140
TSS	0.086
DO	0.167
NO_3-N	0.081
Total phosphate	0.100
Fecal coliform	0.157
Total	**1.000**

The subsequent pollution control strategies were formulated from the interview data and analyzed using the Analytical Hierarchy Process (AHP). Four assessment criteria — ecological, social, institutional, and technical — and eight alternative strategies were identified from in-depth discussions with experts and from relevant theories and applicable regulations on water pollution control. In this study, as many as 10 experts provided pairwise comparisons for the AHP analysis. Each of the xperts completed a pairwise comparison questionnaire for the criteria and the alternatives. The experts represented government agencies, academia, and environmental volunteers.

The judgments of the 10 experts were aggregated into group pairwise comparison matrices before the priority weights were derived. The consistency of the aggregated matrices was evaluated through the consistency ratio (CR), calculated as CR = CI/RI, where CI is the consistency index and RI is the random index. The CR was computed for the aggregated criteria matrix and for each aggregated alternative matrix under the respective criteria. A CR of 0.10 or below was treated as the threshold of acceptable consistency (Frish et al., 2025). The resulting values were 0.043 for the criteria matrix, and 0.072, 0.070, 0.056, and 0.051 for the alternative matrices under the ecological, social, institutional, and technical criteria. All values fell below the threshold, which indicates that the aggregated judgments were consistent enough for priority weight estimation. The aggregated matrices were processed using Expert Choice version 11 and verified manually in Microsoft Excel. The resulting criteria and alternative weights were then used to establish a priority scale for the river pollution control strategies.

In addition, 90 community respondents were surveyed to capture community perceptions and contextual preferences on river restoration and water quality management. These 90 respondents were not involved in the AHP pairwise comparison process, which gives a total of 100 respondents. The community survey data and the expert AHP judgments were treated as two complementary but analytically distinct sources of information

Results and Discussion

Water Quality

This study evaluated the water quality of the Brangkal River using eight parameters — pH, total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, total phosphate, and fecal coliform — based on certified laboratory analyses for March and July 2025. All values were compared with the Class II water quality standards under Government Regulation No. 22 of 2021 (Anggayasti et al., 2024). The complete results are presented in Table 2.

Several parameters stayed within the Class II standards throughout the study. The pH values ranged from 7.51 to 8.71 across all points and periods, which indicates that the river water remained chemically stable; pH is a key parameter that regulates water stability and biological processes (Ramdlan & Azmiyati, 2022). Dissolved oxygen also satisfied the Class II minimum of 4 mg/L at every point, ranging from 4.80 to 5.70 mg/L. Nitrate concentrations stayed within the standard as well, ranging from below 1.00 to 2.40 mg/L. Elevated nitrate in surface water is commonly associated with intensive fertilizer use and ag-

Table 2. Water quality parameters of the Brangkal River, March and July 2025, compared to the Class II standard

No	Parameter	Unit	Class II Std	Up (Mar)	Up (Jul)	Mid (Mar)	Mid (Jul)	Down (Mar)	Down (Jul)
1	pH	–	6–9	7.84	8.71	7.86	8.52	7.51	8.45
2	TSS	mg/L	50	58.9	76	62.8	69.1	34.8	41.7
3	COD	mg/L	25	3.84	8.52	5.44	6.92	<2.91	3.32
4	BOD	mg/L	3	<1.00	4.30	2.75	3.44	<1.00	<1.00
5	DO	mg/L	4 (min.)	4.80	5.70	4.90	5.50	5.20	5.60
6	NO_3	mg/L	10	1.00	1.80	1.60	2.30	<1.00	2.40
7	Total Phosphate	mg/L	0.2	0.157	0.193	0.144	0.205	0.202	0.168
8	Fecal Coliform	MPN/100 mL	1,000	202	16,000	321	16,000	16,000	9,200

ricultural runoff (Hasan et al., 2023), but the values observed here suggest that agricultural activity has not yet exerted significant pressure on nitrate levels in the Brangkal River. COD also met the Class II standard at almost all points. Total phosphate stayed within the standard at every point and period, although its continuous presence indicates a sustained domestic input that carries a longer-term eutrophication risk if it is left unmanaged (Hasan et al., 2023).

The exceedances, however, form a coherent pattern, and that pattern points consistently to one source. TSS exceeded the Class II standard at the upstream and midstream points, ranging from 58.9 to 76 mg/L, while the downstream point stayed compliant. BOD exceeded the Class II standard only during the July 2025 sampling, at the upstream and midstream points, with values of 4.30 and 3.44 mg/L. In March, all points were below the standard. The clearest signal came from fecal coliform. In March 2025, the downstream point already recorded a very high concentration of 16,000 MPN/100 mL, while the upstream and midstream points were still below the Class II limit of 1,000. In July 2025, fecal coliform rose sharply at the upstream and midstream points, reaching 16,000 MPN/100 mL at both, while the downstream point stayed high at 9,200. Microbiological contamination was therefore persistent downstream, and it became more spatially widespread by the July sampling.

Read together, these three parameters tell a single story. TSS, BOD, and fecal coliform are all markers of organic and domestic loading rather than industrial discharge. TSS reflects soil runoff and suspended domestic waste (Sinaga et al., 2025; Istomi et al., 2025). Elevated BOD reflects untreated domestic wastewater, which depletes the oxygen available to aquatic organisms (Anggayasti et al., 2024). Fecal coliform is a direct indicator of human or warm-blooded animal waste (Holcomb & Stewart, 2020). Kitchen waste with oil and food residues, together with detergent-rich laundry wastewater, is known to raise organic and phosphorus loads in receiving waters (Gholami et al., 2023). The concurrent exceedance of these parameters, set against compliant nitrate, phosphate, and DO, indicates that the dominant pressure on the Brangkal River is untreated domestic wastewater and inadequate sanitation in the riverside settlements, rather than agricultural or industrial sources. This finding is consistent with the diagnosis already recorded by the Mojokerto City Environmental Agency (2024), and it is the empirical basis against which the prioritized strategies in Section 3.3 should be connected to.

Water Quality Index (WQI/IKA)

The WQI, and correspondingly the IKA, was calculated and classified following the method established in the Regulation of the Minister of Environment No. 14 of 2025. Across the six measurements — three river segments in March and July 2025 — the scores ranged from 66.33 to 79.12, with an overall mean of 72.71. Every measurement fell within the moderate category ($60 < x \leq 85$). None reached very good range, and none fell into the poor range (Table 3).

Table 3. Water Quality Index (WQI/IKA) scores of the Brangkal River, March and July 2025

River Segment	WQI March 2025	WQI July 2025	IKA Category
Upstream	79.12	66.33	Moderate
Middle	75.23	66.49	Moderate
Downstream	75.84	73.24	Moderate

Overall mean WQI/IKA across all six measurements = 72.71 (Moderate)

The lowest scores occurred at the upstream and midstream points in July 2025 (66.33 and 66.49). All three segments declined from March to July, and the upstream segment declined most sharply, from 79.12 to 66.33. This temporal decline coincides with the July rise in BOD and fecal coliform reported in Section 3.1, which indicates that water quality deteriorated as those organic and microbiological loads increased.

One of the results needs careful interpretation. The downstream point recorded a moderate WQI score in both periods — 75.84 in March and 73.24 in July — even though it carried fecal coliform concentrations of 16,000 and 9,200 MPN/100 mL, far above the Class II limit. This is not a contradiction, but rather a property of the index. The WQI/IKA is an aggregate of eight weighted sub-indices, so a severe exceedance in one parameter can be offset by other parameters that remain compliant, such as pH, COD, DO, and nitrate. A moderate aggregate WQI score does not by itself indicate microbiological safety. The index can mask a severe exceedance in a single parameter. The Brangkal River is classified as moderate on the aggregate score, yet its fecal coliform levels signal substantial microbiological contamination and a real sanitation-related health pressure that the headline index alone does not convey. This limitation should be read alongside the parameter-level results in Section 3.1, not as substitution of them.

AHP Strategic Analysis

The pollution control strategy for the Brangkal River was formulated using the Analytic Hierarchy Process (AHP) (Ramdlan & Azmiyati, 2022), structured as a three-level hierarchy. Figure 1 presents this hierarchical structure. The hierarchy has three levels: the overall goal, the evaluation criteria, and the strategic alternatives. The main goal is to formulate a restoration strategy that improves river water quality through water quality evaluation and through stakeholder involvement in sustainable river management. Four criteria were used to evaluate the alternatives — ecological, social, institutional, and technical aspects. These criteria reflect the multidimensional nature of river restoration, which requires not only ecological improvement but also social participation, institutional coordination, law enforcement, and technical intervention.

Furthermore, eight strategic alternatives were assessed under each criterion: river water quality monitoring, biodiversity enhancement, increased community participation, improvement of community behavior toward the river, law enforcement and environmental monitoring, strengthening collaboration among stakeholders, river normalization and physical rehabilitation, and domestic and industrial waste management systems. The connecting lines indicate that each alternative was evaluated

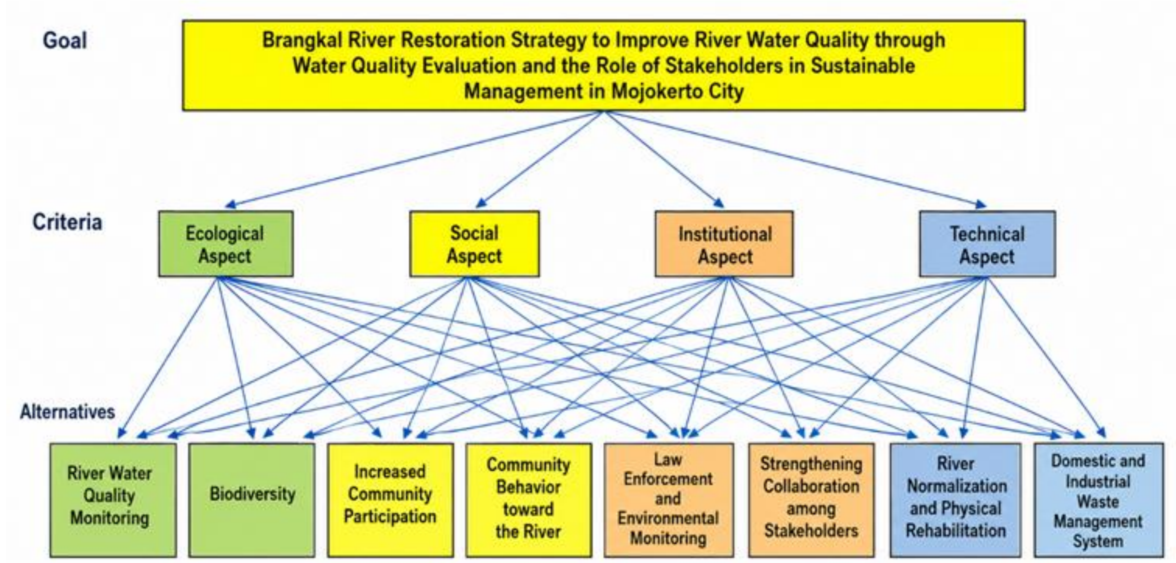

Fig. 1. Hierarchy of Restoration Strategies based on AHP

against all four criteria, which allows the AHP model to identify restoration priorities from integrated stakeholder judgments. The aggregated expert judgments returned an overall consistency ratio of 0.05, below the 0.10 threshold, which confirms that the combined matrix was consistent enough for prioritization.

The criteria weights are the first result that needs attention, because they shape everything that follows. The experts assigned the highest weight to the institutional aspect (38.83%), followed by the technical (25.75%) and social (22.76%) aspects, and the lowest weight to the ecological aspect (12.66%). In other words, the experts framed the restoration of the Brangkal River first as a problem of governance and institutional capacity, and only as a problem of ecological condition. This framing is decisive for interpreting the strategy ranking that follows.

The final priority ranking of the eight alternatives is presented in Figure 2. River water quality monitoring ranked first (17.01%), narrowly ahead of community behavior toward the river (16.58%). These were followed by biodiversity conservation (14.43%), enhancement of community participation (13.35%), environmental law enforcement and supervision (11.73%), river normalization and physical rehabilitation (10.39%), domestic and industrial wastewater management (8.30%), and strengthening coordination among stakeholders (8.22%).

Fig. 2. The priority ranking of the eight alternatives by AHP assay

Monitoring ranked first not because it directly reduces pollution loads, but because the experts considered it the most important enabling strategy. Monitoring provides the diagnostic basis for identifying pollution hotspots, tracking change over time, and directing interventions to where they are needed. In the Brangkal River context, this emphasis is understandable: the city environmental agency's routine monitoring is concentrated on industrial effluent points, while the dominant pressure, as Section 3.1 shows, is domestic. Monitoring should therefore be read as a prerequisite for evidence-based pollution control, not as a stand-alone direct abatement measure.

This interpretation also exposes a genuine tension in the results, and this study states the tension openly rather than smoothing it over. The water quality evidence in Sections 3.1 and 3.2 points clearly to untreated domestic wastewater as the dominant source of pollution — elevated TSS, the July rise in BOD, and persistent high fecal coliform. Yet the AHP placed domestic and industrial wastewater management seventh of eight (8.30%). This low weight was not incidental. The strategy scored consistently low across all four criteria, from 8.06% to 8.57%. The apparent mismatch between the diagnostic evidence and the priority ranking is best explained by the criteria weighs. Because the experts weighed the ecological aspect lowest and the institutional aspect highest, the prioritization favored strategies that support diagnosis, institutional coordination, and adaptive management over strategies that directly target the physical pollution source. The AHP result is therefore internally consistent with its own criteria structure. It reflects how the experts framed the problem, rather than a ranking of the pollution sources themselves.

Two points follow. First, the AHP ranking should be read as a stakeholder-based prioritization of restoration strategies, not as a ranking of pollution sources. The two need not coincide, and here they do not. The available expert judgment data records the weights but not the reasoning behind them, so this study does not speculate on whether the low weight given to wastewater management reflects considerations of cost, feasibility, or jurisdictional authority. Second, the result reveals a conceptual limitation worth stating plainly: the highest-ranked strategy is diagnostic rather than corrective.

Monitoring should not be treated as a stand-alone solution. It is an enabling and governance-support mechanism that must be followed by concrete pollution-reduction action. Given the water quality evidence, wastewater management deserves greater operational priority than its AHP weight alone would suggest. This divergence between expert-perceived priority and diagnostic evidence is itself a finding. It indicates that strategy selection for the Brangkal River is currently shaped more by institutional framing than by the measured condition of the river — the very disconnect this study set out to examine.

Conclusion

This study evaluated the water quality of the Brangkal River in Mojokerto City and formulated pollution control strategies through the Analytic Hierarchy Process. Based on the Water Quality Index, the river falls within the moderate category, with an overall mean WQI/IKA score of 72.71. This indicates that the river still retains its ecological and social functions, but it does not indicate microbiological safety. The aggregate index masks severe exceedances in individual parameters, and the elevated total suspended solids, biological oxygen demand, and fecal coliform observed during the study point to a dominant pressure from untreated domestic wastewater and inadequate sanitation in the riverside settlements. Water quality also declined at all three river segments between March and July 2025, which indicates that the pressure on the river is intensifying rather than stable.

The AHP analysis prioritized river water quality monitoring (17.01%) and the improvement of community behavior toward the river (16.58%) as the leading strategies. These were followed by biodiversity conservation, enhancement of community participation, law enforcement and supervision, physical rehabilitation, wastewater management, and stakeholder coordination. This ranking should be read as a stakeholder-based prioritization of restoration strategies rather than a ranking of pollution sources. Monitoring is best understood as an enabling strategy that provides the diagnostic basis for evidence-based intervention. It is not in itself a pollution-reduction measure, and it must be followed by concrete corrective action. Because the water quality evidence identifies domestic wastewater as the dominant source, the strengthening of household sanitation and domestic wastewater management in the riverside settlements deserves greater operational priority than its AHP weight alone would suggest. Effective restoration of the Brangkal River therefore depends on integrating ecological, social, technical, and institutional measures, and on sustained coordination among the city environmental agency, local communities, and other stakeholders. These findings provide an evidence-based foundation for local efforts toward Sustainable Development Goal 6 (SDG 6) on clean water and sustainable water resource management.

This study has several limitations. The water quality assessment was based on two sampling periods in 2025, which capture the seasonal contrast but not longer-term trends. The expert judgment data record the AHP weights but not the reasoning behind them, so the study could not explain why particular strategies received higher or lower priority. The Water Quality Index, as an aggregate measure, may also understate the severity of individual parameters such as fecal coliform. Future research should address these gaps through longer-term monitoring, studies of the river's carrying capacity and pollution load capacity, ecological assessment of the river system, and the development of community-based river management models.

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