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Assessment of Water Carrying Capacity and Pollution Load in the Tiku Sub-Watershed, Indonesia

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Abstract
Water resources are a critical component of regional development, especially in areas experiencing rapid land-use changes. Assessing both the quantity and quality of water is essential to ensure long-term environmental sustainability and human well-being. This study aims to assess the water carrying capacity and pollution load in the Tiku Sub-Watershed, located in Musi Rawas Utara Regency, Indonesia. The evaluation combines hydrological availability analysis with water quality assessment to determine the balance between water supply and its environmental sustainability. The results reveal a paradoxical condition: although the annual surface water availability is abundant, reaching approximately 96.13 million m^3 *with a dependable flow rate of 3.05* m^3/s*, the water quality is critically degraded. Pollution indices show an average score of 6.65, indicating moderate pollution status. Laboratory analyses of eight sampling points indicate that concentrations of mercury (Hg), cadmium (Cd), phosphate (*PO_4^{3-}*), and ammonia (*NH_3*) consistently exceed the national water quality standards. None of the observed locations meet the permissible thresholds, demonstrating a severely limited assimilative capacity of the aquatic environment. Water demand is primarily driven by land-based economic activities (98.26%), while domestic use accounts for only 1.74%. The carrying capacity index (criticality ratio) is 0.12, suggesting that current water use remains within sustainable limits. However, the low assimilative capacity underscores urgent concerns for pollution control and integrated watershed management. These findings highlight the necessity for stricter regulation of pollutant sources and sustainable land use practices to protect water resources in the Tiku Sub-Watershed.*
Keywords: *water carrying capacity; pollution load; watershed management; heavy metal contamination*

INTRODUCTION

Water resources play a vital role in supporting environmental resilience and sustainable development, particularly in regions experiencing intense land-use pressure. In the context of watersheds, both the quality and quantity of water are heavily influenced by human activities, especially land-use changes, population growth, and environmentally unfriendly economic practices. These pressures often lead to the degradation of hydrological functions, reduced water availability, and increased levels of pollution, which ultimately threaten the ecological integrity of the watershed and the well-being of communities that depend on it [1], [2], [3]. The assessment of water carrying capacity serves as a crucial approach to determine the extent to which a region can provide and sustain water resources without undergoing ecological degradation. This concept integrates both the availability of water and the ecosystem's ability to absorb pollution from human activities. A comprehensive evaluation of carrying capacity is essential for guiding sustainable land use planning and water resource management, especially in areas facing increasing environmental pressures [4], [5], [6].

The Tiku Sub-watershed, located in Musi Rawas Utara Regency, is currently facing environmental pressure due to artisanal and small-scale gold mining (ASGM) activities in the upstream area. These mining operations are typically conducted using traditional and unregulated methods, often involving mercury (Hg) as an amalgamation agent, which directly contaminates water bodies [7], [8]. In addition to mercury, mining activities also contribute to increased sedimentation and the presence of other heavy metals such as cadmium (Cd), further degrading the physical and chemical quality of the water [9]. The accumulation of heavy metals from artisanal and small-scale gold mining (ASGM) negatively affects the assimilative capacity of aquatic environments, leading to a decline in biodiversity and increasing health risks for communities living downstream. Prolonged exposure to contaminants such as mercury and cadmium can bioaccumulate in aquatic organisms, entering the food chain and posing long-term health threats. Moreover, the disruption of ecological balance in the watershed can compromise the provision of essential ecosystem services, including clean water supply and habitat stability [10], [11], [12].

Pollution loads from artisanal and small-scale gold mining (ASGM) activities are often chronic and difficult to manage, as they originate from non-point sources that are dispersed both spatially and temporally. This diffuse nature of contamination complicates monitoring efforts and makes it challenging to implement targeted mitigation strategies. As a result, pollutants can persist in the environment over long periods, gradually accumulating and causing long-term ecological and public health impacts [13]. Therefore, integrating water quantity (hydrological) and water quality (chemical and toxicological) assessments is essential to understand the cumulative impacts on environmental carrying capacity. Parameters such as mercury (Hg) and cadmium (Cd) concentrations, along with pollution indices, are widely used in various studies to evaluate contamination levels resulting from artisanal and small-scale gold mining (ASGM) in watersheds. These indicators provide a comprehensive picture of both acute and long-term pollution risks, enabling more informed decision-making for watershed management and pollution control [14], [15]. The decline in water carrying capacity due to chronic pollution from artisanal and small-scale gold mining (ASGM) can significantly reduce the ecosystem's ability to provide essential environmental services, such as clean water and aquatic habitats. When the assimilative capacity of water bodies is exceeded, ecological functions begin to deteriorate, affecting both biodiversity and water usability. Over time, this degradation can compromise the sustainability of watershed resources and the livelihoods of communities that depend on them [16].

Several studies in tropical regions and developing countries have shown that artisanal and small-scale gold mining (ASGM) often operates outside formal regulatory frameworks and is difficult to control both technically and socially. These operations are typically informal, lacking environmental oversight and proper waste management practices. As a result, efforts to mitigate their environmental impacts face significant challenges, including limited enforcement capacity, socioeconomic dependency, and resistance from local communities [17], [18], [19], [20], [21]. This situation leads to an increased risk of long-term heavy metal pollution and makes the watershed rehabilitation process particularly difficult. In Indonesia, although ASGM activities provide employment opportunities for many local workers, their impact on water resources is substantial, especially in upstream areas that serve as the primary sources of surface water. The degradation of these headwaters not only affects water quality downstream but also threatens the overall sustainability of the watershed system [22].

Based on this background, the present study aims to evaluate the water carrying capacity and pollution load in the Tiku Sub-watershed, with a particular focus on the impacts of artisanal and small-scale gold mining (ASGM) activities in the upstream area. The assessment adopts an integrative approach that combines water availability analysis and water quality evaluation, emphasizing heavy metal concentrations and pollution index parameters. The findings of this study are expected to provide both scientific and practical contributions to ecosystem-based watershed management and serve as a foundation for more effective and sustainable pollution control policies in regions affected by traditional gold mining practices.

MATERIALS AND METHODS

This study employed a descriptive quantitative approach that integrates both water quality and quantity analyses to evaluate the environmental carrying and assimilation capacity of the Tiku Sub-watershed. The research was conducted during September to October 2024 in the Tiku Sub-watershed area Musi Rawas Utara Regency, Indonesia. The primary method used for assessing water quality is the Pollution Index (PI), while water quantity is analyzed using a water balance and criticality ratio approach based on annual water demand and availability. The study was conducted spatially, covering eight water sampling points distributed across the upstream, middle, and downstream sections of the river. The analyzed parameters include COD, BOD, Hg, NO_2, NO_3, PO_4, NH_3, Pb, Cd, Ni, Cu, and DO, with concentrations measured in mg/L.

For plankton sampling, 50 liters of water were collected quantitatively and compositely using a bucket and filtered through a 50 μm plankton net. Samples were taken from both the right and left banks of the river at each station. The collected plankton samples were then transferred into 30 mL plastic containers and preserved with five drops of 4% formalin solution.

Water Quality Analysis

Water quality assessment was conducted by calculating the Pollution Index (PI), a method used to determine the status of surface water quality based on the comparison between the concentration of a pollutant parameter (Ci) and the water quality standard (Lij) established for Class II usage, in accordance with Indonesian Government Regulation No. 82 of 2001. The PI calculation was carried out using the following formula:

$$PI = \frac{\sqrt{\left(\frac{Ci}{Sij}\right)max^2 + \left(\frac{Ci}{Sij}\right)ever^2}}{2} \quad (1)$$

where PI = Nemerow Index, Ci = measured concentrationfrom evaluation factor class i, and Sij = standard concen-tration of evaluation factor for water purpose class j. Te correlation between PI value and water classifcationincludes PI < 1.0: clean, 1 < PI < 2: mild pollution, 2 < PI < 3:moderate pollution, 3 < PI < 5: polluted, and PI > 5: ex-tremely polluted categories.

Water quantity analysis

Water quantity analysis was conducted to evaluate the balance between water availability and water demand. Water demand was calculated based on two main components: (a) Domestic water demand, which refers to SNI 6728.1:2015 standard of 43.2 m³ per capita per year, adjusted by a correction factor of 2; and (b) Land-based economic activities, including irrigated rice fields, plantations, dryland farming, and mixed-use agriculture, using a formula that accounts for land area, cropping intensity, and standard water consumption rates. The total water demand was obtained by summing these two components. Surface water availability was calculated using an annual water balance approach, with the reliable flow rate (Q90) used as the key indicator. Q90 represents the minimum streamflow expected to be available 90% of the time throughout the year. Water availability was estimated using the following formula:

$$\text{Surface Water } (m^3/year) = \text{Flow rate} \times 60 \times 60 \times 24 \times 365 \quad (2)$$

This estimation considered rainfall, evaporation, land use, and the hydrological characteristics of the watershed area, thereby providing a more representative picture of water availability in both spatial and temporal dimensions.

Assessment of Water Carrying and Assimilative Capacity

The assessment of water carrying capacity was conducted using the Criticality Ratio (CR) approach, which is the ratio between water withdrawal (W) and water availability (Wa) [23]:

$$CR = W/Wa \quad (3)$$

The CR values were classified into five categories of water stress, ranging from "very low" to "very high," and then converted into carrying capacity scores using a Likert scale from 1 to 5. The safe threshold is based on international standards such as the Falkenmark Indicator which considers 1,000 m³ per capita per year as the minimum requirement to avoid water scarcity. This indicator provides a clear measure of pressure on water resources by reflecting the balance between supply and demand.

Meanwhile, the assimilative capacity was assessed based on the results of the Pollution Index (PI) and the percentage of monitoring points that met Class II water quality standards. This percentage was then classified into five categories—ranging from very high to very low assimilative capacityalso using a Likert scale from 1 to 5, as established by the Ministry of Environment and Forestry [23].

RESULTS

3.1. Water Quality in the Tiku Sub-Watershed

The assessment of water quality in the Tiku Sub-Watershed revealed a critical level of pollution, particularly concerning organic pollutants and heavy metals. All sampling points exhibited Chemical Oxygen Demand (COD) values ranging from 48 to 134 mg/L, significantly exceeding the Class II threshold of 25 mg/L. Elevated levels of Biological Oxygen Demand (BOD) were also observed at points 4, 7, and 8, surpassing the standard limit of 3 mg/L. Dissolved Oxygen (DO) concentrations across all locations fell below the minimum acceptable threshold of 4 mg/L, with the lowest value recorded at 0.26 mg/L, indicating hypoxic conditions. Notably, mercury (Hg) and cadmium (Cd) concentrations exceeded permissible levels at all sampling points, with maximum values of 0.11 mg/L and 0.03 mg/L, respectively. Furthermore, phosphate (PO_4^{3-}) concentrations were alarmingly high (ranging from 9.79 to 11.79 mg/L), and ammonia (NH_3) levels exceeded standards at most locations. In contrast, nitrite (NO_2) and nitrate (NO_3) concentrations remained within safe limits, as did lead (Pb), nickel (Ni), and copper (Cu), which were consistently below regulatory thresholds (Table 1).

The pollution index analysis at eight sampling points within the Tiku Sub-Watershed revealed values ranging from 5.35 to 6.97, with an average index of 6.65 (Table 2). According to national water quality classification standards, these values fall within the category of moderately polluted. This classification indicates a substantial decline in water quality across all monitoring sites, with concentrations of key pollutants exceeding the permissible thresholds established for Class II water use. The findings reflect the cumulative impact of organic contaminants and heavy metals, underscoring the need for urgent mitigation strategies to restore aquatic health and ensure compliance with environmental regulations.

Table 1. Comparison of Water Quality Parameters with Class II Quality Standards in the Tiku Sub-Watershed

Parameter	Standard (Class II)*	T1	T2	T3	T4	T5	T6	T7	T8
COD (mg/L)	25.00	48	83	84	60	114	108	134	119
BOD (mg/L)	3.00	1.25	0.95	0.87	3.02	2.54	2.55	3.03	2.91
Hg (mg/L)	0.00	0.065	0.037	0.040	0.053	0.045	0.041	0.042	0.110
NO_2 (mg/L)	0.06	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
NO_3 (mg/L)	10.00	1.31	2.45	1.15	1.36	1.52	0.91	1.21	1.29
PO_4^{3-} (mg/L)	0.20	10.77	10.16	9.79	11.38	11.79	3.32	10.77	11.35
NH_3 (mg/L)	0.02	0.08	0.02	0.10	0.07	0.09	0.09	0.06	0.08
Pb (mg/L)	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cd (mg/L)	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Ni (mg/L)	0.02	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Cu (mg/L)	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
DO (mg/L)	4.00 (min)	0.26	0.83	2.77	3.51	3.36	3.73	3.84	3.80

Source: Primary Data (2024), *Water Quality Standards PP RI No. 22 of 2021 class II lamp VI

Table 2. Pollution Index and Water Quality Status at Sampling Points in the Tiku Sub-Watershed.

Sampling Point	Pollution Index	Water Quality Status
1	6.83	Moderately Polluted
2	6.74	Moderately Polluted
3	6.68	Moderately Polluted
4	6.91	Moderately Polluted
5	6.97	Moderately Polluted
6	5.35	Moderately Polluted
7	6.83	Moderately Polluted
8	6.91	Moderately Polluted
Average	6.65	Moderately Polluted

3.2. Water Quantity in the Tiku Sub-Watershed

Household water demand in the Tiku Sub-Watershed has shown a marked increase from 2020 to 2024, corresponding with population growth during the same period. In 2020, the population was recorded at 2,224 inhabitants, with a total domestic water demand of 192,153.6 m³/year. By 2024, the population rose to 2,468, with water demand reaching 213,235.2 m³/year. The average household water demand over the five-year period was 204,871.7 m³/year. This increase in water consumption—amounting to 21,081.6 m³/year—is directly correlated with the population growth of 244 people from 2020 to 2024 (Table 3), reflecting the proportional relationship between demographic dynamics and water resource requirements.

Table 3. Household water demand based on population in the Tiku Sub-Watershed (2020–2024).

No	Year	Population (persons)	Household Water Demand (m³/year)
1	2020	2,224	192,153.6
2	2021	2,347	202,780.8
3	2022	2,386	206,150.4
4	2023	2,431	210,038.4
5	2024	2,468	213,235.2
	Average		204,871.7

Water demand for land-based economic activities in the Tiku Sub-Watershed, Musi Rawas Utara Regency, exhibited relatively minor fluctuations between 2020 and 2024, with a moderate upward trend particularly evident in the plantation sector. The total annual water demand ranged from 11,549,952 m³ to 11,622,528 m³, averaging 11,590,387.2 m³/year during the five-year period. The paddy field sector consistently accounted for the largest share of water consumption, with an average of 8,393,932.8 m³/year, representing approximately 72.4% of total demand. The plantation sector recorded an average annual demand of 2,998,425.6 m³ (25.9%), showing a steady increase from 2,908,224 m³ in 2020 to 3,094,848 m³ in 2024, likely due to expansion and intensification of perennial crops such as oil palm and rubber. In contrast, the livestock sector exhibited the lowest water demand, averaging 198,028.8 m³/year (1.7% of the total), with a slight declining trend over the same period potentially linked to reduced livestock populations or improvements in water use efficiency (Table 4).

Table 4. Annual Water Demand by Land-Based Economic Sectors in the Tiku Sub-Watershed (2020–2024)

Year	Plantation (m³/year)	Rice Field (m³/year)	Livestock (m³/year)	Total Demand (m³/year)
2020	2,908,224	8,439,552	202,176	11,549,952
2021	2,962,656	8,439,552	202,176	11,604,384
2022	2,993,760	8,398,080	196,992	11,588,832
2023	3,032,640	8,356,608	196,992	11,586,240
2024	3,094,848	8,335,872	191,808	11,622,528
Average	2,998,425.6	8,393,932.8	198,028.8	11,590,387.2

The total water demand in the Tiku Sub-Watershed, Musi Rawas Utara Regency, during the 2020–2024 period remained relatively high and stable, with a slight increase from 11,742,105.60 m³ in 2020 to 11,835,763.20 m³ in 2024. The average annual water demand over the five-year period was 11,795,258.88 m³, reflecting a sustained pressure on local water resources (Table 5 and Figure 1). Based on the most recent annual data, total demand reached 11,754,823.68 m³/year, with the vast majority attributed to land-based economic activities, such as agriculture, plantations, and livestock. In contrast, domestic water consumption accounted for only a small fraction of the total. This uneven distribution highlights a significant disparity in water utilization, where economic sectors dominate water usage, while household needs remain comparatively minimal. Such imbalance underscores the importance of integrated water resource management strategies to ensure sustainability, particularly in regions where economic activities place intense demand on available water supplies.

Table 5. Annual Total Water Demand in the Tiku Sub-Watershed (2020–2024)

Year	Domestic Water Demand (m³/year)	Land-Based Economic Water Demand (m³/year)	Total Water Demand (m³/year)
2020	192,153.60	11,549,952	11,742,105.60
2021	202,780.80	11,604,384	11,807,164.80

2022	206,150.40	11,588,832	11,794,982.40
2023	210,038.40	11,586,240	11,796,278.40
2024	213,235.20	11,622,528	11,835,763.20
Average			11,795,258.88

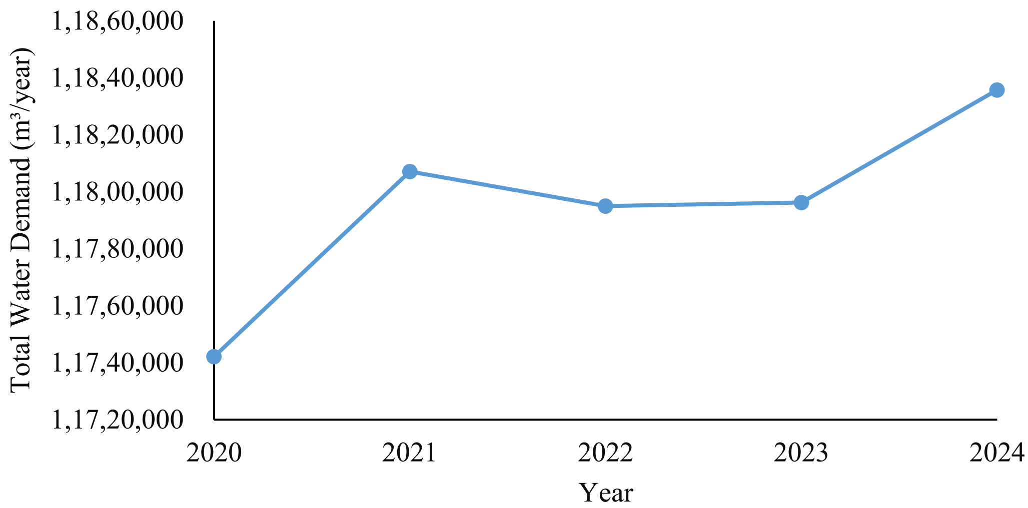

Figure 1. Trend of total water needs in the Tiku Sub-DAS

Watershed is 3.05 m³/second, corresponding to an annual surface water availability of approximately 96,129,689.98 m³. This availability exhibits significant seasonal variation, with peak volumes observed in April (22,556,780.05 m³) and February (19,394,759.53 m³), reflecting the influence of the tropical monsoon climate (Table 6). In contrast, during the dry season months—particularly September and October—the dependable discharge drops sharply to 0.11 m³/second, with water availability declining to 3,351,299.38 m³ and 3,611,156.76 m³, respectively. These values highlight the temporal imbalance in water distribution within the watershed. The average total water demand, combining domestic and land-based economic sectors, is estimated at 11.79 million m³/year, or approximately 982,938 m³/month. When compared to the annual surface water availability, the Tiku Sub-Watershed is generally in a condition of water surplus on an annual scale. However, the pronounced intra-annual variability suggests the need for seasonal water management strategies to mitigate potential short-term deficits during dry periods and enhance water storage and distribution efficiency.

Table 6. Monthly Reliable Discharge and Surface Water Availability in the Tiku Sub-Watershed

Month	Reliable Discharge (90%) (m³/s)	Surface Water Availability (m³/year)
January	0.19	6,127,566.68
February	0.62	19,394,759.53
March	0.22	6,833,468.34
April	0.72	22,556,780.05
May	0.23	7,143,152.36
June	0.15	4,863,127.27
July	0.18	5,635,427.21
August	0.13	4,032,942.60
September	0.11	3,351,299.38
October	0.11	3,611,156.76

November	0.13	4,168,681.33
December	0.27	8,411,328.48
Total	3.05	96,129,689.98

3.3. Water Carrying Capacity and Assimilative Capacity in the Tiku Sub-Watershed

The sustainability of water resources in a watershed can be evaluated using the Criticality Ratio (CR) or Water Demand–Supply Index (WDSI), which compares the total annual water demand with the total annual surface water availability. This index provides a quantitative assessment of the extent to which available water resources can support domestic and productive water uses. In the case of the Tiku Sub-Watershed, located in Musi Rawas Utara Regency, the study revealed that the total annual water demand, including both domestic consumption and land-based economic activities (i.e., agriculture, plantations, and livestock), amounted to 11,795,258.88 m^3/year. In comparison, the annual surface water availability, derived from 90% dependable flow (Q90), reached 96,129,689.98 m^3/year. From these figures, the calculated Criticality Ratio was 0.12, indicating that only 12% of the available water is currently utilized. According to established water carrying capacity classifications, a CR value below 0.25 is categorized as “high” carrying capacity, corresponding to a Likert score of 4, which reflects a condition in which water supply far exceeds demand [23].

Table 7. Water Demand, Surface Water Availability, and Water Carrying Capacity Index (IKP) in the Tiku Sub-Watershed

Water Demand (m^3/year)	Surface Water Availability (m^3/year)	Criticality Ratio (IKP)	Score	Carrying Capacity Classification
11,795,258.88	96,129,689.98	0.12	4	High

Based on the results presented in Table 8, the Tiku Sub-Watershed is classified as having very poor water quality, characterized by pollution across all monitoring points. According to widely adopted water quality evaluation frameworks, this condition falls into the “very low” or “poor” category, as less than 20% of sampling locations meet the Class II water quality standards. These findings indicate that the majority of observation sites fail to comply with the Indonesian Government Regulation No. 22/2021 on Water Quality Standards for Class II usage, which includes purposes such as aquaculture, irrigation, and recreational activities. The widespread failure to meet these thresholds reflects a significant deterioration of water quality and a limited assimilative capacity of the watershed to handle pollution loads. This degradation of water quality, if left unmanaged, can severely compromise the sustainability of both ecosystem services and socioeconomic activities dependent on the watershed.

Table 8. Compliance Level of Water Quality Standards in the Tiku Sub-Watershed

Number of Sampling Points	Percentage of Points Meeting Quality Standards (%)	Compliance Criteria
8	0	Very Low

DISCUSSION

The findings of this study indicate that the water quality in the Tiku Sub-Watershed is under significant pollution pressure, primarily due to elevated concentrations of organic pollutants and heavy metals. Chemical Oxygen Demand (COD) values range from 48 to 134 mg/L, substantially exceeding the Class II water quality standard of 25 mg/L. Similarly, Biological Oxygen Demand (BOD) levels surpassed the threshold of 3 mg/L at multiple sampling points, indicating a heavy load of organic pollutants entering the water body. Moreover, Dissolved Oxygen (DO) levels were critically low across all sampling sites, with the lowest recorded at 0.26 mg/L, suggesting hypoxic conditions that threaten the survival of aquatic organisms [24], [25].

This situation is further exacerbated by heavy metal contamination, particularly mercury (Hg) and cadmium (Cd), which recorded maximum concentrations of 0.11 mg/L and 0.03 mg/L, respectively both exceeding permissible limits. These concentrations pose a significant risk of toxic bioaccumulation in aquatic biota and human populations [26], [27]. Additionally, phosphate (PO_4^{3-}) and ammonia (NH_3) levels were alarmingly

high, ranging from 9.79 to 11.79 mg/L and 0.02 to 0.10 mg/L, respectively. These nutrients accelerate eutrophication, reduce dissolved oxygen levels, and promote harmful algal blooms, with serious implications for water quality and public health [28], [29]. Although nitrate (NO_3) and nitrite (NO_2) concentrations in the Tiku Sub-Watershed remain within permissible limits, they do not compensate for the excessive levels of other pollutants. Elevated concentrations of COD, BOD, mercury, cadmium, phosphate, and ammonia dominate the water quality profile, resulting in a degraded aquatic environment. This imbalance highlights that compliance with only a few parameters cannot ensure ecological safety or water usability [30], [31], [32]. This condition is reflected in the average Water Pollution Index (WPI) score of 6.65, classifying the water as moderately polluted [33]. This level suggests a significant degree of degradation and the urgent need for mitigation measures. None of the eight sampling sites met the Class II water quality standards, confirming the very low environmental assimilative capacity [23]. One of the major contributors to this pollution is unregulated artisanal and small-scale gold mining (ASGM), which involves the indiscriminate use of mercury (Hg) and other hazardous chemicals, frequently discharged directly into nearby water bodies without undergoing any form of treatment [34], [35]. Mercury used in ASGM can persist in the environment, bioaccumulate in aquatic organisms, and pose serious health risks to humans through the food chain [36], [37]. Moreover, ASGM activities typically result in widespread deforestation and destruction of riparian vegetation, thereby increasing runoff, exacerbating erosion, and contributing to sedimentation in rivers and stream [38], [39], [40]. These physical changes degrade aquatic habitats, reduce biodiversity, and compromise the water system's ability to self-purify. Additionally, sediments contaminated with heavy metals can resuspend during high-flow events, prolonging exposure risks and making water quality management increasingly difficult [41]. Collectively, these impacts severely disrupt the ecological balance of freshwater ecosystems and undermine the sustainable use of water resources for agriculture, domestic use, and fisheries.
In contrast to the deteriorating water quality, the quantity of available water in the Tiku Sub-Watershed is relatively abundant. The annual reliable discharge was calculated at 3.05 m^3/s, translating to a total surface water availability of approximately 96.13 million m^3/year, which far exceeds the annual water demand of 11.80 million m^3. This results in a Criticality Ratio (CR) of 0.12, categorized as high carrying capacity (Likert score = 4), indicating that the pressure on water availability remains very low [42], [43], [44]. This surplus suggests that, from a quantity standpoint, the watershed currently has sufficient capacity to support domestic and land-based economic activities such as agriculture and livestock, provided that water resources are managed sustainably and pollution sources are adequately controlled.
However, the distribution of water demand across sectors is highly uneven. Approximately 98.26% of the total water use is attributed to land-based economic activities, such as agriculture, plantations, and livestock, whereas domestic consumption accounts for only 1.74%. Rice cultivation is the largest water consumer, followed by plantations and livestock farms, reflecting a land use pattern dominated by intensive agricultural practices [45], [46]. These systems inherently require high volumes of water for irrigation and animal maintenance, making them particularly vulnerable to seasonal water fluctuations. The disproportionate allocation of water also suggests that any changes in water availability or quality would have significant implications for regional food security and rural livelihoods [47], [48]. Sustainable water allocation strategies and efficient irrigation technologies are therefore critical to ensure long-term resilience of the watershed.
Despite the high water availability, the poor water quality severely limits the usability of the resource without adequate treatment. This creates a paradoxical situation where the region possesses abundant water in terms of quantity but lacks the quality required for safe consumption, irrigation, and ecosystem sustainability. The elevated concentrations of pollutants, including heavy metals and nutrients, not only jeopardize aquatic life but also pose long-term risks to public health through bioaccumulation and waterborne diseases [49], [50], [51]. If these conditions persist, the capacity of the watershed to support economic development particularly agriculture, aquaculture, and domestic needs will be significantly constrained. Therefore, addressing water quality challenges is crucial to unlocking the full socio-economic potential of the Tiku Sub-Watershed and ensuring environmental resilience [52].

Therefore, a comprehensive and sustainable water resource management strategy is urgently needed. Recommended interventions include:

- Strict enforcement against illegal mining activities, particularly artisanal and small-scale gold mining (ASGM) operations;
- Rehabilitation of riparian buffer zones and watershed vegetation;
- Implementation of water-saving irrigation systems;
- Development of wastewater treatment infrastructure, and
- Construction of water storage systems, such as embung (small reservoirs) and retention ponds.

Restoring water quality is essential not only for aquatic ecosystem recovery, but also for enabling the safe, efficient, and sustainable use of water resources to support both domestic needs and economic activities.

CONCLUSIONS

The research results show that although the Tiku Sub-watershed in North Musi Rawas Regency has a high water carrying capacity, with surface water availability reaching 96.13 million m³ per year and a Criticality Ratio of 0.12, water quality in this area is in a very concerning condition. All sampling points showed pollutant parameter values, such as mercury, cadmium, phosphate, and ammonia, that exceeded safe thresholds. This is reflected in the average pollution index value of 6.65, indicating a moderate pollution category and indicating very limited environmental capacity for pollution. Water demand in the Tiku Sub-watershed is dominated by the land-based economic sector (98.26%), primarily agriculture, while the household sector contributes only 1.74% of total demand. This imbalance between abundant water quantity and poor water quality underscores the importance of integrated environmental quality management interventions to support the sustainability of water resources in this region.

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