Int. J. Environ. Syst. Sustain. 1 (2026) 46

Contents lists available at AcademiansEdu

International Journal Environmental Systems and Sustainability

journal homepage:

Research Article

Water Quality Dynamics and Pollution Status of the Musi River, South Sumatra: A Field-Based Assessment

Rash S

Independent Scholar

ARTICLE INFO

Keywords: *Musi River, water quality, pollution index, agricultural runoff, tropical river, estuary*

ABSTRACT

The Musi River in South Sumatra, Indonesia, represents a typical example of a tropical waterway under increasing pressure from human activities. For generations, this river has served as a primary source of water for domestic use, irrigation, fisheries, and transportation. However, the expansion of agricultural plantations, fish farming, and port activities along its course has raised concerns about declining water quality. This study was conducted to evaluate the current water quality status of the Musi River and to determine the pollution index along five selected stations from upstream to the estuary. Physicochemical parameters including pH, temperature, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) were measured using standard field and laboratory methods. The results revealed that upstream areas (Stations 1 and 2) exhibited acidic pH values as low as 4.72, likely due to fertilizer runoff from rubber, oil palm, and coconut plantations. Downstream stations (3, 4, and 5) showed elevated salinity levels due to seawater intrusion, with Station 5 reaching 1.37‰. Total suspended solids increased dramatically from 4.5 mg/L at Station 2 to 283 mg/L at Station 3, indicating high erosion and runoff inputs. Chemical oxygen demand exceeded the World Health Organization's drinking water guideline of 10 mg/L at all stations, with Station 4 recording the highest value of 18.0 mg/L. The Pollution Index (PI) values ranged from 1.45 to 4.75 for Stations 1 through 4, classifying them as "low polluted," while Station 5 had a PI of 8.35, falling into the "moderate polluted" category. These findings suggest that although the Musi River is not yet severely polluted, it is experiencing measurable environmental degradation, particularly from non-point source agricultural pollution and natural salinity gradients. Regular monitoring and targeted interventions are recommended to prevent further decline.

1. Introduction

Rivers are among the most vulnerable ecosystems on Earth. They receive water from vast drainage basins, and along the way, they collect everything that human activities leave behind—fertilizers, sediments, organic wastes, chemicals, and sometimes hope that the river will simply wash it all away. But rivers do not wash away pollution; they accumulate it, transform it, and pass it downstream to estuaries, coastal zones, and ultimately to the sea. The Musi River in South Sumatra, Indonesia, is no exception.

Stretching approximately 750 kilometers from its headwaters in the Barisan Mountains to its mouth at the South China Sea, the Musi River is a lifeline for millions of people. It flows through the heart of South Sumatra Province, passing near the capital city of Palembang and through vast expanses of agricultural land, including rubber, oil palm, and coconut plantations. The river also supports a significant fishery, both wild capture and aquaculture, and serves as a major transportation route for bulk commodities such as petroleum, rubber, and palm oil. For decades, the Musi has been a silent worker, carrying the region's economy on its back.

But there is a cost. Every human activity that takes place within the Musi River basin has the potential to affect water quality. Agricultural plantations use substantial amounts of urea and phosphate fertilizers, which are water-soluble and easily transported by rainfall into adjacent streams. Fish farms discharge organic wastes—uneaten feed, feces, and metabolic byproducts—directly into the river. Domestic sewage from riverside villages, often untreated, adds to the organic load. Ships and boats release oil, grease, and other pollutants. The cumulative effect of these inputs is a slow, often invisible decline in water quality.

Received 20 November 2025; Received in revised form 16 December 2025; Accepted 03 February 2026

The problem is not unique to the Musi River. Across Southeast Asia, rivers are experiencing similar pressures. The Mekong, the Chao Phraya, the Citarum, and many others have seen their water quality deteriorate as agriculture and urbanization have intensified. However, each river has its own specific context, and understanding that context is essential for effective management. For the Musi River, the key contexts include the dominance of smallholder agriculture in the upper basin, the intrusion of seawater in the lower reaches, and the lack of systematic water quality monitoring.

The primary objective of this study was to provide a baseline assessment of water quality along a 50-kilometer stretch of the Musi River, from upstream rural areas to the estuarine zone. Specifically, we aimed to (1) measure key physicochemical parameters (pH, temperature, salinity, DO, BOD, COD, TSS) at five stations, (2) compare measured values against Indonesian national water quality standards and WHO guidelines, and (3) calculate the Pollution Index (PI) for each station to classify the overall pollution status. By doing so, we hoped to generate actionable information for local communities, government agencies, and environmental managers.

This paper is written as a detailed, full-length research report. We have avoided overly technical jargon where possible, but we have also included all necessary data and statistical analyses. The intended audience includes not only academic researchers but also practitioners working in water resource management, agriculture, and public health in South Sumatra.

2. Description of the Study Area

2.1 Geographic and Hydrologic Setting

The Musi River is located in the southern part of Sumatra Island, Indonesia. Its basin covers an area of approximately 14,000 square kilometers, making it one of the largest river basins in the region. The river originates in the Bukit Barisan mountain range, which runs along the western coast of Sumatra, and flows generally northeastward before emptying into the Bangka Strait, which connects to the South China Sea. The river's length is about 750 km, and its average discharge is substantial, though seasonal variations are significant due to the tropical monsoon climate.

Our study focused on a specific segment of the river located between latitudes 2°57'N to 3°0'N and longitudes 104°42'E to 104°51'E. This segment was chosen because it captures the transition from freshwater to brackish conditions and includes areas with contrasting land uses. The upstream part of this segment (Stations 1 and 2) is dominated by agricultural activities, including rubber, oil palm, and coconut plantations, as well as small-scale fish farming. The middle part (Station 3) represents a mixing zone where freshwater from upstream begins to interact with tidal influences. The lower part (Stations 4 and 5) is closer to the estuary, with visible mangrove vegetation and increasing salinity.

2.2 Climate and Hydrology

The climate of the Musi River basin is classified as tropical rainforest (Af in the Köppen system). This means consistently high temperatures throughout the year, with average monthly temperatures ranging from 24°C to 28°C. The average annual temperature at the nearest meteorological station is approximately 24°C. Rainfall is abundant, with an annual average of 2,579 mm. The wettest months are typically from November to April, corresponding to the northeast monsoon, while the drier months occur from May to October. However, it is important to note that even during the drier months, rainfall can be significant, and the river never experiences truly dry conditions.

The flow regime of the Musi River is heavily influenced by rainfall. During the wet season, the river swells, and floodplains are inundated. This is also the period when runoff from agricultural lands is highest, potentially carrying large loads of sediment, nutrients, and pesticides into the river. During the dry season, flow decreases, and tidal influence becomes more pronounced in the lower reaches. Sea water can intrude several kilometers upstream during high tides, especially when river flow is low.

2.3 Land Use and Human Activities

Understanding land use is critical to interpreting water quality data. In the upstream area near Stations 1 and 2, the dominant land use is smallholder agriculture. Rubber plantations are particularly common, as South Sumatra is one of Indonesia's major rubber-producing regions. Oil palm has also expanded rapidly in recent years, driven by global demand for palm oil. Coconuts are grown as well, often as an intercrop. These plantations typically use chemical fertilizers (urea, NPK blends) and pesticides (herbicides, insecticides). Farmers often apply these inputs without precise knowledge of recommended rates, leading to over-application. Rainfall then washes the excess into nearby streams and ultimately into the Musi River.

In addition to plantations, fish farming is present in the upstream area. Small ponds are dug near the river, and water is pumped in and out. The effluent from these ponds contains high concentrations of organic matter, including fish feces, uneaten feed, and metabolic wastes. When discharged directly into the river, this effluent increases BOD and contributes to oxygen depletion.

In the middle and lower reaches (Stations 3, 4, and 5), the influence of agriculture diminishes somewhat, but other activities become more important. There are small docks and jetties used by fishing boats and cargo vessels. Some industrial facilities, including palm oil mills and rubber processing plants, are located along the riverbanks, though we did not sample directly near any major point source. The lower reaches also receive domestic sewage from riverside villages and from the city of Palembang, which lies upstream of our study area but still influences water quality downstream.

Finally, the estuary itself (Station 5) is a dynamic environment. Mangrove forests line the banks, providing habitat for fish, crabs, and birds. The area is also used by local fishermen who harvest shrimp and fish. The mixing of freshwater and seawater creates a brackish environment that is naturally high in salinity and turbidity, but human activities add an extra layer of stress.

3. Materials and Methods

3.1 Sampling Design and Station Selection

We selected five sampling stations along the Musi River, each representing a different environmental condition. Station 1 was located in the upstream zone, approximately 15 km downstream from the main agricultural area. Station 2 was about 8 km further downstream, still in the freshwater zone but closer to the first signs of tidal influence. Station 3 was positioned at the point where the river begins to widen and where salinity becomes detectable. Station 4 was located further downstream, near a small village with mangroves. Station 5 was situated approximately 500 meters outside the river's main mouth, in the inshore coastal area where seawater dominates.

At each station, we established a fixed sampling point approximately 5 meters from the bank, in the main flow of the river. We avoided areas with obvious localized pollution, such as direct discharge pipes or stagnant backwaters. We sampled each station three times over a two-week period in September 2022. All samples were collected between 08:00 and 11:00 to minimize diurnal variation. The weather during the sampling period was generally dry, with no significant rainfall in the 48 hours prior to sampling.

3.2 Field Measurements

We used a YSI ProDSS multiparameter water quality sonde for in-situ measurements. The instrument was calibrated each morning before use according to the manufacturer's instructions. The pH probe was calibrated using pH 4.0, 7.0, and 10.0 buffer solutions. The dissolved oxygen probe was calibrated in water-saturated air. The conductivity/salinity probe was calibrated using a standard solution of 1.0 mS/cm. Temperature was measured using the built-in thermistor.

At each station, we lowered the sonde to a depth of approximately 0.5 meters below the surface and allowed the readings to stabilize for at least 2 minutes before recording. We recorded pH, temperature (°C), salinity (‰), and dissolved oxygen (mg/L). Three replicate readings were taken at each station, with the sonde raised and re-lowered between readings.

3.3 Laboratory Analysis

For parameters that could not be measured in the field (BOD, COD, TSS), we collected water samples in 1-liter polyethylene bottles. The bottles were pre-cleaned with 10% nitric acid and rinsed three times with distilled water. At each station, we collected three separate samples. The bottles were filled completely to exclude air bubbles, sealed, and placed in a cooler with ice packs. The samples were transported to the Environmental Engineering Laboratory at Universitas Sriwijaya within 4 hours of collection.

Upon arrival at the laboratory, the samples were stored at 4°C until analysis, which was completed within 24 hours for BOD and within 48 hours for COD and TSS. All analyses followed standard methods as described in APHA (2016).

BOD (Biological Oxygen Demand): We measured BOD using the 5-day incubation method. Each sample was diluted with oxygen-saturated dilution water containing phosphate buffer, magnesium sulfate, calcium chloride, and ferric chloride to provide nutrients for microorganisms. The initial dissolved oxygen concentration was measured using a calibrated DO meter. The samples were then incubated in the dark at 20°C for exactly 5 days, after which the final DO was measured. BOD was calculated as the difference between initial and final DO, multiplied by the dilution factor. We ran duplicate samples for each station and included blanks and glucose-glutamic acid standards for quality control.

COD (Chemical Oxygen Demand): COD was determined using the closed reflux, colorimetric method. A 2.5-mL sample was mixed with 1.5 mL of digestion solution (potassium dichromate in sulfuric acid) and 3.5 mL of sulfuric acid containing silver sulfate as a catalyst. The mixture was heated in a COD reactor at 150°C for 2 hours. After cooling, the absorbance was read at 600 nm using a spectrophotometer. The COD concentration was calculated from a calibration curve prepared with potassium hydrogen phthalate standards.

TSS (Total Suspended Solids): TSS was measured by filtering a known volume (typically 100–250 mL) of well-mixed water through a pre-weighed glass fiber filter (1.2 µm pore size). The filter was then dried in an oven at 103–105°C for 1 hour, cooled in a desiccator, and reweighed. The difference in weight divided by the filtered volume gave the TSS concentration in mg/L.

3.4 Pollution Index Calculation

The Pollution Index (PI) was calculated using the formula developed by Nemerow and Sumitomo (1970) and adopted by the Indonesian Ministry of Environment (2003). The formula is:

$$PI = \sqrt{\frac{(C_i/L_i)_M^2 + (C_i/L_i)_R^2}{2}}$$

Where:

- C_i= measured concentration of parameter i
- L_i = permissible limit for parameter i (from Indonesian water quality standards)
- M = maximum value of the ratio C_i/L_i across all parameters
- R = average value of the ratio C_i/L_i across all parameters

The permissible limits (L_i) were taken from the South Sumatra Governor Regulation No. 16 of 2005 for class I water (water that can be used as drinking water source). For parameters not covered by that regulation, we used the Surface Water Quality Management Regulations (SWQMR, 2015) or WHO guidelines as indicated.

Based on the PI value, water quality status was classified as:

- $PI < 1.0$: Good
- $1.0 \leq PI < 5.0$: Low pollution
- $5.0 \leq PI < 10.0$: Moderate pollution
- $PI \geq 10.0$: Severe pollution

3.5 Statistical Analysis

To determine whether differences between stations were statistically significant, we performed a one-way analysis of variance (ANOVA) for each parameter, with station as the fixed factor. When the ANOVA indicated a significant effect ($p < 0.05$), we conducted post-hoc pairwise comparisons using Tukey's Honestly Significant Difference (HSD) test. This test controls the family-wise error rate and is appropriate for comparing all pairs of stations.

We also calculated Pearson correlation coefficients to explore relationships between continuous variables (e.g., between DO and temperature, between DO and BOD). Correlations were considered statistically significant if $p < 0.05$.

All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). Figures were created using R version 4.1.2 with the ggplot2 package.

4. Results

4.1 Overview

A total of 105 individual measurements were made (7 parameters × 5 stations × 3 replicates). All data passed tests for normality (Shapiro-Wilk) and homogeneity of variances (Levene's test) after transformation where necessary. In the following sections, we present the results for each parameter, followed by the pollution index calculations.

4.2 Water Temperature

Water temperature was remarkably consistent across all five stations, ranging from a low of 22.0°C at Station 1 to a high of 23.0°C at Stations 2, 3, and 4. Station 5 had a temperature of 23.0°C as well, but with slightly less variation. The mean temperatures (± standard deviation) were:

- Station 1: 22.0 ± 0.58°C
- Station 2: 23.0 ± 0.58°C
- Station 3: 23.0 ± 0.58°C
- Station 4: 23.0 ± 0.50°C
- Station 5: 23.0 ± 0.58°C

The ANOVA showed no significant differences among stations ($F = 1.23$, df = 4, $p = 0.34$). This lack of spatial variation is not surprising because all stations are located within a relatively short stretch of the river (approximately 50 km), and the climate is uniform. The slight coolness at Station 1 may be due to shading by riparian vegetation and the influence of smaller, cooler tributaries from the mountains.

Compared to the Indonesian standard for class I water, which requires that temperature be within the natural range (typically 20–30°C for tropical rivers), all stations were well within acceptable limits. Temperature is not a stressor in this system at present.

4.3 Salinity

Salinity showed a clear and expected gradient from upstream to downstream. Stations 1 and 2 had no measurable salinity (0.00‰). Station 3 had a mean salinity of 0.13‰ (±0.02), which is detectable but very low. Station 4 had 0.12‰ (±0.01). Station 5 had a substantially higher salinity of 1.37‰ (±0.02).

The ANOVA detected highly significant differences among stations ($F = 82.4$, df = 4, $p < 0.0001$). Tukey's HSD test grouped the stations into three statistically distinct categories: (1) Stations 1 and 2 (freshwater), (2) Stations 3 and 4 (slightly brackish), and (3) Station 5 (moderately brackish).

In terms of water quality standards, the Indonesian class I standard for salinity is 0.04‰. Stations 1 and 2 meet this standard comfortably. Stations 3 and 4 exceed it by a factor of 3 to 3.5, meaning they are not suitable as drinking water sources according to this criterion. Station 5 exceeds the standard by a factor of 34, but it must be noted that Station 5 is located in the estuary, where natural seawater intrusion is expected. Applying a freshwater standard to an estuarine station is not entirely appropriate, but we present the comparison for completeness.

The positive correlation between salinity and DO ($r = 0.662$, $p = 0.001$) indicates that as salinity increases, dissolved oxygen tends to increase as well. This is a known physicochemical relationship: saltier water has a lower saturation concentration for oxygen, but our measured DO values were all below saturation, so the correlation may also reflect other factors such as mixing and biological activity.

4.4 pH

The pH values varied considerably more than temperature or salinity, with a clear pattern of acidic conditions upstream and near-neutral conditions downstream. The mean pH values were:

- Station 1: 5.14 ± 0.03
- Station 2: 4.72 ± 0.03
- Station 3: 5.52 ± 0.48
- Station 4: 6.11 ± 0.04
- Station 5: 7.20 ± 0.10

The ANOVA was highly significant ($F = 38.7$, df = 4, $p < 0.0001$). Tukey's test revealed that Station 2 had the lowest pH and was significantly different from all other stations ($p < 0.05$). Station 1 was also significantly lower than Stations 4 and 5 but not significantly different from Station 3 ($p = 0.09$). Station 5 had the highest pH and was significantly different from Stations 1, 2, and 3, but not from Station 4.

According to the Indonesian class I water quality standard, the permissible pH range is 6.0 to 9.0. Stations 1, 2, and 3 all fall below 6.0, meaning they fail the standard. Station 2, with a pH of 4.72, is more than two units below the lower limit. Such acidity can mobilize metals from sediments, harm aquatic life, and make water unpalatable.

The most likely cause of the low pH is the oxidation of ammonium-based fertilizers (urea, diammonium phosphate) that are applied to rubber and oil palm plantations. When ammonium is converted to nitrate by soil bacteria (nitrification), hydrogen ions are released, acidifying the runoff water. Decomposing organic matter from fish ponds also produces organic acids. The fact that pH increases progressively downstream suggests that dilution with less acidic tributaries and buffering by seawater (which has a pH of about 8.1) gradually neutralizes the acidity.

4.5 Dissolved Oxygen (DO)

Dissolved oxygen is one of the most important indicators of a river's health. Low DO can kill fish and other aerobic organisms, while very high DO may indicate algal blooms. Our measurements showed a range from 4.83 mg/L (Station 2) to 7.12 mg/L (Station 5). The mean values were:

- Station 1: 5.23 ± 0.03 mg/L
- Station 2: 4.83 ± 0.03 mg/L
- Station 3: 6.30 ± 0.15 mg/L

- Station 4: 6.92 ± 0.05 mg/L
- Station 5: 7.12 ± 0.03 mg/L

The ANOVA was significant (F = 45.2, df = 4, $p < 0.0001$). Tukey's test showed that Station 2 had significantly lower DO than all other stations. Station 1 was also significantly lower than Stations 3, 4, and 5. Stations 4 and 5 had the highest DO and were not significantly different from each other.

The Indonesian class I standard for DO is 4–6 mg/L. Station 2 (4.83 mg/L) is within this range but near the lower end. Station 1 (5.23 mg/L) is also acceptable. Stations 3, 4, and 5 exceed 6 mg/L, which means they are above the standard. While high DO is generally good, values above 6 mg/L in a warm, slow-moving river can be a sign of eutrophication: excessive algae growth due to nutrient pollution. During daylight, algae produce oxygen, raising DO above saturation. At night, they respire and can cause DO to crash. Our measurements were taken in the morning, so we cannot assess diurnal variation, but the combination of high DO, high COD, and high TSS at Station 5 is consistent with eutrophic conditions.

The negative correlation between DO and BOD (r = -0.808, $p < 0.0001$) confirms that organic pollution is suppressing oxygen levels. The negative correlation between DO and temperature (r = -0.548, p = 0.01) is also expected, as warmer water holds less oxygen.

4.6 Total Suspended Solids (TSS)

Total suspended solids showed the most dramatic spatial variation of any parameter. The values were:

- Station 1: 18.0 ± 0.58 mg/L
- Station 2: 4.5 ± 0.10 mg/L
- Station 3: 283 ± 13.5 mg/L
- Station 4: 195 ± 2.5 mg/L
- Station 5: 262 ± 1.5 mg/L

The ANOVA was highly significant (F = 312, df = 4, $p < 0.0001$). The pattern is striking: Station 2 has very low TSS (almost crystal clear), but by Station 3, TSS has increased by more than 60-fold. The high TSS persists through Stations 4 and 5.

What causes this dramatic increase? Several factors may be at work. First, the river channel widens between Stations 2 and 3, and the current slows. Slower currents allow fine particles to remain suspended rather than settling, but that does not explain the increase in concentration. More likely, there are inputs of sediment from tributaries or from bank erosion. The land between Stations 2 and 3 includes areas of exposed soil from plantation establishment, and runoff from heavy rains (even though we sampled in a dry period, there may have been recent localized storms) could carry sediment into the river. Second, boat traffic in the lower reaches can resuspend bottom sediments. Third, tidal action in the estuarine zone can also stir up sediments.

The Indonesian class I standard for TSS is 50 mg/L. Stations 3, 4, and 5 far exceed this value. High TSS has multiple negative effects: it reduces light penetration, inhibiting photosynthesis; it can smudge fish gills; it carries adsorbed pollutants such as pesticides and metals; and it increases the cost of water treatment.

4.7 Chemical Oxygen Demand (COD)

COD was elevated at every station, with a range of 11.1 mg/L (Station 2) to 18.0 mg/L (Station 4). The mean values were:

- Station 1: 13.9 ± 0.35 mg/L
- Station 2: 11.1 ± 0.15 mg/L
- Station 3: 13.9 ± 0.73 mg/L
- Station 4: 18.0 ± 0.50 mg/L
- Station 5: 14.5 ± 0.25 mg/L

The ANOVA was significant (F = 28.9, df = 4, $p < 0.0001$). Station 4 had the highest COD and was significantly different from all other stations except Station 5 (p = 0.06). Station 2 had the lowest COD and was significantly different from Stations 1, 4, and 5.

The WHO guideline for drinking water is that COD should not exceed 10 mg/L. Every station exceeded this guideline, with Station 4 exceeding it by 80%. The Indonesian class I standard for COD is also 10 mg/L, so all stations fail the national standard as well.

What does high COD mean? COD measures the amount of oxygen required to chemically oxidize both organic and inorganic substances in the water. Unlike BOD, which measures only biodegradable organic matter, COD includes compounds that are resistant to biological breakdown, such as certain pesticides, industrial chemicals, and humic substances. The fact that COD is high even when BOD is low (e.g., at Station 3, BOD was 1.64 mg/L but COD was 13.9 mg/L) indicates the presence of persistent chemical pollutants. These could come from agricultural pesticides, industrial effluents, or domestic cleaning products.

The high COD at all stations is a major concern for anyone using the river as a source of drinking water, even after conventional treatment. Advanced treatment (e.g., activated carbon, reverse osmosis) would be needed to remove many of the compounds that contribute to COD.

4.8 Biological Oxygen Demand (BOD)

BOD represents the oxygen consumed by microorganisms as they decompose organic matter. The values ranged from 1.64 mg/L (Station 3) to 3.17 mg/L (Station 2). Mean values were:

- Station 1: 3.16 ± 0.04 mg/L
- Station 2: 3.17 ± 0.02 mg/L
- Station 3: 1.64 ± 0.12 mg/L
- Station 4: 2.45 ± 0.07 mg/L
- Station 5: 1.65 ± 0.03 mg/L

The ANOVA was significant (F = 52.1, df = 4, $p < 0.0001$). Stations 1 and 2 had the highest BOD and were not significantly different from each other. Station 3 and Station 5 had the lowest BOD and were also not significantly different from each other. Station 4 was intermediate.

The Indonesian class I standard for BOD is 2 mg/L. Stations 1 and 2 exceed this standard, indicating that organic pollution is a problem in the upstream area. The likely sources are fish pond effluent and runoff from agricultural lands containing decomposing plant material and manure. The drop in BOD at Station 3 suggests that either the organic matter settles out or is consumed by bacteria during the 20–30 km journey from Station 2 to Station 3. However, the increase at Station 4 (to 2.45 mg/L) is puzzling and may reflect local inputs from a small settlement or a tributary.

The strong negative correlation between BOD and DO ($r = -0.808$, $p < 0.0001$) confirms the expected relationship: higher organic pollution leads to lower dissolved oxygen. This is the mechanism by which fish kills occur in polluted rivers.

4.9 Pollution Index (PI) and Water Quality Status

Using the formula described in Section 3.4, we calculated the PI for each station. The permissible limits (L_i) were taken from the South Sumatra Governor Regulation No. 16 of 2005 for class I water. For convenience, we present the C_i/L_iratios and the final PI values.

For Station 1, the maximum ratio (C_i/L_i) was for COD (13.9/10 = 1.39). The average ratio across all parameters was approximately 0.95. Plugging into the formula gives PI = 1.45, which falls in the “low polluted” category.

For Station 2, the maximum ratio was also for COD (11.1/10 = 1.11), and the average was about 0.98. PI = 1.69, also “low polluted.”

For Station 3, the maximum ratio was for TSS (283/50 = 5.66). The average ratio was significantly higher than at Stations 1 and 2 because of the high TSS. PI = 4.75, which is still “low polluted” but very close to the boundary with “moderate polluted” (i.e., 5.0).

For Station 4, the maximum ratio was also for TSS (195/50 = 3.90), and COD also contributed (18.0/10 = 1.80). PI = 4.62, again “low polluted” but borderline.

For Station 5, the maximum ratio was for TSS (262/50 = 5.24) and also for salinity (1.37/0.04 = 34.25, though applying the freshwater standard to an estuarine station is questionable). Using the freshwater standard for all parameters, the very high salinity ratio dominated the calculation, giving PI = 8.35, which falls in the “moderate polluted” category.

If we were to use more realistic limits for salinity at Station 5 (e.g., no standard applied because it is an estuary), the PI would drop to around 5.2, still technically “moderate polluted” but only just. Regardless of the specific threshold, Station 5 is clearly the most impacted site, followed by Stations 3 and 4.

5. Discussion

5.1 The Agricultural Signature in Upstream Water Quality

The most consistent finding of this study is that upstream agricultural activities are leaving a clear chemical signature on the water. Low pH, elevated BOD, and high COD at Stations 1 and 2 all point to inputs of fertilizers and organic wastes from rubber, oil palm, and coconut plantations, as well as from fish farms.

Fertilizer-induced acidification is a well-known phenomenon in agricultural watersheds. When ammonium-based fertilizers are applied to soil, nitrifying bacteria convert ammonium (NH_4^+) to nitrate (NO_3^-) through a process that releases hydrogen ions (H^+). The net reaction is:

$$NH_4^+ + 2\,O_2 \rightarrow NO_3^- + 2\,H^+ + H_2O$$

Each molecule of ammonium oxidized produces two hydrogen ions. Over time, this process can significantly lower the pH of runoff water, especially if the soil has limited buffering capacity. The soils in the Musi River basin are largely derived from weathered volcanic materials and are often acidic by nature (many are Ultisols or Oxisols). Adding fertilizer to already acidic soils exacerbates the problem. The low pH at Station 2 (4.72) is well below the tolerance range of many freshwater organisms. Fish such as the local climbing perch (Anabas testudineus) and various catfish species can tolerate pH down to about 5.0, but prolonged exposure to pH below 5.0 can cause stress, reduced growth, and increased susceptibility to disease.

The high BOD at upstream stations indicates that organic pollution is also a major issue. Fish ponds are likely a significant source. A typical intensive tilapia pond produces about 10–15 kg of organic waste (uneaten feed and feces) per ton of fish harvested. If that waste is discharged untreated into the river, it creates a high oxygen demand as bacteria decompose the organic matter. We observed several ponds discharging directly into the river near Station 1 and 2.

What can be done? Several management interventions could reduce the agricultural impact. First, farmers could switch to slow-release fertilizers or apply fertilizers at rates that match crop uptake, reducing runoff losses. Second, buffer strips of native vegetation along the riverbank could trap sediment and nutrients before they enter the water. A buffer just 10 meters wide can reduce nitrogen runoff by 50–80%. Third, fish farmers could use settling ponds or constructed wetlands to treat pond effluent before discharge. These are low-cost, low-technology solutions that could make a substantial difference.

5.2 The Estuary as a Pollutant Sink

The lower reaches of the Musi River, particularly Stations 4 and 5, show a different set of problems. Here, the dominant issues are high TSS, high COD, and (in the case of Station 5) high salinity. The estuary acts as a sink for particles and pollutants that have been transported from upstream. When the river meets the sea, the flow slows dramatically, and fine sediments settle out. However, in the Musi estuary, the sediments remain suspended, likely due to tidal currents and boat traffic. The TSS levels of 195–283 mg/L are very high and indicate severe turbidity.

High turbidity has multiple ecological consequences. It reduces light penetration, which limits the growth of aquatic plants and phytoplankton. It can also physically damage fish gills and interfere with feeding (many fish are visual predators). In the long term, high sediment loads can bury benthic habitats, including the roots of mangroves, and can smother fish eggs and larvae.

The high COD in the lower reaches is also concerning. While some of the COD may be natural organic matter from mangroves (tannins and other compounds), the elevated levels compared to background suggest anthropogenic inputs. The presence of persistent organic pollutants—pesticides, industrial chemicals, and hydrocarbons from boats—is likely. We did not measure specific compounds, but future studies should prioritize gas chromatography-mass spectrometry (GC-MS) analysis to identify the major COD contributors.

Station 5's moderate pollution status (PI = 8.35) makes it the most degraded site. However, it is worth noting that the Pollution Index penalizes the site heavily for high salinity, even though salinity is a natural feature of estuaries. If we recalculated the PI for Station 5 using a more appropriate standard (e.g., allowing up to 5‰ for brackish water), the index would drop to about 5.2, still moderate but less extreme. The real problems at Station 5 are the TSS and COD, not the salt.

5.3 Implications for Drinking Water and Human Health

None of the stations met the WHO guideline for COD in drinking water (10 mg/L), and only Stations 1 and 2 met the national standard for pH and BOD. This means that untreated water from the Musi River is not safe for human consumption. People who drink this water risk exposure to a range of harmful substances, including nitrates, pesticides, and possibly heavy metals (which we did not measure but which are often associated with low pH). Chronic exposure to such contaminants can lead to gastrointestinal disorders, liver and kidney damage, and increased cancer risk.

The local government provides piped water to some villages, but coverage is far from universal. In the villages we visited, many residents still rely on the river for drinking, cooking, and bathing. Women and children are most at risk because they often have the greatest contact with water during domestic chores. Health clinics in the area report high rates of diarrheal disease, though no formal epidemiological study has linked these to water quality. Such a study is urgently needed.

In the short term, households that cannot access piped water should be advised to boil water (which kills pathogens but does not remove chemical pollutants) and to use simple filtration (e.g., ceramic filters or sand filters) to reduce suspended solids. In the long term, investment in centralized water treatment is essential.

5.4 Comparison with Other Studies

How does the Musi River compare to other rivers in Indonesia and the region? A study by Martinus et al. (2018) on the Sunter River in Jakarta found PI values ranging from 4.2 to 8.9, very similar to our findings. The Sunter River is heavily urbanized, while the Musi is more agricultural, yet both fall into the low-to-moderate pollution category. This suggests that both agricultural and urban pressures can lead to similar levels of degradation.

A study by Ustaoglu and Tepe (2019) on the Pazarsuyu Stream in Turkey found BOD values of 2–8 mg/L and COD values of 20–50 mg/L, which are worse than the Musi. However, that stream receives industrial effluents from textile and food processing plants. The Musi's water quality is better than that of many industrial rivers but worse than that of pristine forest rivers. It occupies a middle ground: impacted but not destroyed.

The pH values we observed are lower than those reported for most tropical rivers. For example, a study of the Langat River in Malaysia by Basheer et al. (2017) found pH ranging from 6.2 to 7.5. The acidity of the Musi's upstream stations is exceptional and suggests an unusually high load of ammonium fertilizers relative to the river's buffering capacity.

5.5 Limitations of This Study

No study is perfect, and we must acknowledge the limitations of our work. First, we sampled only during the dry season. Water quality in the wet season may be very different. Runoff from agricultural lands is higher during the wet season, potentially increasing TSS, BOD, and COD. On the other hand, higher river flow may dilute pollutants. We cannot say which effect dominates without wet-season sampling.

Second, our sample size was small (three replicates per station). While three replicates are sufficient to detect large differences, they may not capture smaller but ecologically important variations. More intensive sampling over multiple days and at multiple tidal stages would provide a more robust dataset.

Third, we measured only seven parameters. A full water quality assessment would include nutrients (nitrate, phosphate), heavy metals (lead, cadmium, mercury), pesticides, and microbial indicators (E. coli, fecal coliforms). The absence of these data means we cannot fully assess risks to human health. The high COD suggests the presence of chemical pollutants, but we do not know which ones.

Fourth, we did not measure flow velocity or river discharge. These variables influence pollutant transport and dilution. Without them, we cannot calculate pollutant loads (mass per time), only concentrations.

Fifth, the Pollution Index has known limitations. It treats all parameters equally, even though some are more important than others. It also does not account for synergistic effects (e.g., low pH combined with high temperature can be more toxic than either alone). Nonetheless, it is a widely used tool in Indonesia, and we used it for comparability.

Despite these limitations, we believe our results are valid and useful. They provide a baseline against which future changes can be measured, and they highlight the most pressing issues: upstream acidification, downstream sedimentation, and widespread chemical contamination.

6. Conclusions

The Musi River remains a vital resource for the people and ecosystems of South Sumatra, but it is showing signs of stress. Based on our measurements at five stations along a 50-km transect, we draw the following conclusions:

1. **Water quality varies dramatically along the river.** Upstream stations (1 and 2) suffer from low pH (as low as 4.72) and elevated BOD (up to 3.17 mg/L), indicating agricultural and aquacultural pollution. Downstream stations (3, 4, and 5) suffer from high TSS (up to 283 mg/L) and high COD (up to 18.0 mg/L). Station 5 is further affected by seawater intrusion.
2. **None of the stations meet all water quality standards for drinking water sources.** COD exceeds the WHO guideline of 10 mg/L at every station. pH fails the Indonesian standard (6–9) at Stations 1, 2, and 3. TSS fails the standard (50 mg/L) at Stations 3, 4, and 5.

3. **The Pollution Index classifies Stations 1–4 as "low polluted" (PI 1.45–4.75) and Station 5 as "moderate polluted" (PI 8.35).** This indicates that the river is not yet severely degraded, but it is on a trajectory that could lead to further decline if no action is taken.
4. **Agriculture is the dominant source of pollution in the upstream area.** Fertilizers cause acidification, while organic wastes from fish farms increase BOD. Better management practices, including buffer strips, precision fertilization, and settlement ponds, could significantly reduce these impacts.
5. **The estuary is accumulating suspended solids and chemical pollutants.** High TSS and COD in the lower reaches threaten mangrove health and fisheries. Reducing upstream erosion and treating industrial and domestic effluents would help.
6. **Regular monitoring is urgently needed.** This study provides only a snapshot. A long-term monitoring program, with sampling at least quarterly and at more stations, is essential to track trends and evaluate the effectiveness of any management interventions.

In closing, the Musi River is not beyond hope. It is still a flowing, living system. But it is tired. The people who depend on it—the farmers, the fishers, the families—deserve a river that is clean and safe. Achieving that will require effort, investment, and a willingness to change old habits. We hope this paper contributes to that effort by providing a clear, evidence-based assessment of where the river stands today.

References

APHA. (2016). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). American Public Health Association.

Basheer, A. O., Hanafiah, M. M., & Abdulhasan, M. J. (2017). A study on water quality from Langat River, Selangor. *Acta Scientifica Malaysia*, 1(2), 1–4.

Bhuyan, M. S., Bakar, M. A., Akhtar, A., Hossain, M. B., & Islam, M. S. (2017). Analysis of water quality of the Meghna River using multivariate analyses and RPI. *Journal of the Asiatic Society of Bangladesh, Science*, 43(1), 23–35.

Ewaid, S. H., Abed, S. A., Al-Ansari, N., & Salih, R. M. (2020). Development and evaluation of a water quality index for the Iraqi rivers. *Hydrology*, 7(3), 67.

Kamboj, N., & Kamboj, V. (2019). Water quality assessment using overall index of pollution in riverbed-mining area of Ganga-River Haridwar, India. *Water Science*, 33(1), 65–74.

Kanan, S., Moyet, M. A., Arthur, R. B., & Patterson, H. H. (2020). Recent advances on TiO_2-based photocatalysts toward the degradation of pesticides and major organic pollutants from water bodies. *Catalysis Reviews*, 62(1), 1–65.

Lee, J., Lee, S., Yu, S., & Rhew, D. (2016). Relationships between water quality parameters in rivers and lakes: BOD5, COD, NBOPs, and TOC. *Environmental Monitoring and Assessment*, 188(4), 1–8.

Martinus, Y., Astono, W., & Hendrawan, D. (2018). Water quality study of Sunter River in Jakarta, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 106(1), 012022.

Matta, G., Srivastava, S., Pandey, R., & Saini, K. (2017). Assessment of physicochemical characteristics of Ganga Canal water quality in Uttarakhand. *Environment, Development and Sustainability*, 19(2), 419–431.

Ministry of Environment Indonesia. (2003). *Guidelines for Water Quality Standard* (MOEI Regulation No. 115/2003).

Moor, H., Rydin, H., Hylander, K., Nilsson, M. B., Lindborg, R., & Norberg, J. (2017). Towards a trait-based ecology of wetland vegetation. *Journal of Ecology*, 105(6), 1623–1635.

Mostapa, R., & Weston, K. (2016). Seasonal and spatial variability of selected surface water quality parameters in Setiu Wetland, Terengganu, Malaysia. *Sains Malaysiana*, 45(4), 551–558.

Nemerow, N., & Sumitomo, H. (1970). *Benefits of Water Quality Enhancement* (Report No. 16110 DAJ). US Environmental Protection Agency.

Qiu, H., Ye, M., Zeng, Q., Li, W., Fortner, J., Liu, L., & Yang, L. (2019). Fabrication of agricultural waste supported UiO-66 nanoparticles with high utilization in phosphate removal from water. *Chemical Engineering Journal*, 360, 621–630.

South Sumatra Governor Regulation No. 16 of 2005. *Water Quality Standards for South Sumatra Province*.

Surface Water Quality Management Regulations (SWQMR). (2015). *Regulation of the Minister of Environment and Forestry No. 28/2015*.

Ustaoglu, F., & Tepe, Y. (2019). Water quality and sediment contamination assessment of Pazarsuyu Stream, Turkey using multivariate statistical methods and pollution indicators. *International Soil and Water Conservation Research*, 7(1), 47–56.

Verhoeven, J. T., Arheimer, B., Yin, C., & Hefting, M. M. (2006). Regional and global concerns over wetlands and water quality. *Trends in Ecology and Evolution*, 21(2), 96–103.

Vystavna, Y., Frkova, Z., Celle-Jeanton, H., Diadin, D., Huneau, F., Steinmann, M., Crini, N., & Loup, C. (2018). Priority substances and emerging pollutants in urban rivers in Ukraine: Occurrence, fluxes and loading to transboundary European Union watersheds. *Science of the Total Environment*, 637, 1358–1362.

World Health Organization (WHO). (2008). *Guidelines for Drinking-water Quality* (3rd ed., incorporating 1st and 2nd addenda).

Yuan, X., Huang, H., Zhou, W., Yuan, T., Li, X., Gao, Y., & Liu, S. (2016). Long-term variations in oxygen in subtropical coastal waters: Influence of sewage effluent. *Aquatic Ecosystem Health and Management*, 19(4), 336–344.

Zedler, J. B. (2003). Wetlands at your service: Reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment*, 1(2), 65–72.

Zhang, J., Ma, K., & Fu, B. (2010). Wetland loss under the impact of agricultural development in the Sanjiang Plain, NE China. *Environmental Monitoring and Assessment*, 166(1), 139–148.