International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 10-04-2026, Accepted: 11-05-2026, Published: 26-05-2026
Volume 11, Issue 2, 2026, Page No. 82-86

The analysis of total suspended solids in the downstream Mahakam River, Kutai Kartanegara District, East Kalimantan, Indonesia

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Abstract
Downstream of a river of Mahakam represent an estuarine area. This area shows the flow rate of the water has decreased, the bed has expanded, the depth has decreased. The color of the water has changed due to turbidity, suspended solids and plankton. The temperature of the water increased and the amount of dissolved oxygen decreased. It is characterized by dense anthropogenic activities, ranging from residential settlements to transportation traffic, which potentially trigger an increase in sediment loading. This study aims to analyze the concentration of Total Suspended Solids (TSS) and its distribution on the basis of the tides. The study was performed in month of September 2025, a purposive sampling method was used to decide the locations to collect the data from 15 sampling sites. TSS concentration was analyzed using gravimetric method, spatial mapping by using the Inverse Distance Weighted (IDW) interpolation technique, and data were processed by using Spearman Rank correlation analysis. The concentration of TSS of each sampling site above may could be affected and related to land use such as settlements (sampling site 6), industrial zones (sampling site 13, 14). Statistical tests confirmed a very strong and significant negative correlation between TSS concentration and dissolved oxygen (DO) ($r = -0.988$\$; $p < 0.01$). Meanwhile, the correlation with current velocity was found to be non-significant ($p > 0.05$), affirming that sediment dynamics are predominantly controlled by human intervention, local morphology, and tidal fluctuations rather than natural river current factors. The results showed that the concentration of TSS ranging from 14.88 to 39.98 mg/L indicating still within the permissible limit according to Government Regulation PPRI No. 22 year 2021. Spatially, the highest concentration of TSS 39.98 mg/L was found at sampling site 10 then followed by sampling site 7, and at sampling site 11 and 12.

Keywords: Dissolved oxygen, non-parametric statistic, spearman correlation, suspended sediment, tides, tropical river ecosystem, water quality assessment

Introduction

The Mahakam River serves as a vital economic and transportation artery in East Kalimantan, particularly in its downstream reaches, which are characterized by dense residential areas, industrial docks, and intensive coal barge traffic. A complex mixing of freshwater from Mahakam river and seawater from the Makassar Strait, making it highly productive yet vulnerable to environmental pressures (Bengen, 2002) [2], high anthropogenic pressure, notably from dense water transportation, significantly influences the physical condition of the waters (Wardhana, 2006) [13]. This often leads to a decrease in water quality, potentially disrupting aquatic life and ecosystem functions.

A primary indicator of declining water quality in this region is the elevated concentration of Total Suspended Solids (TSS), which consist of organic and inorganic materials suspended in water with a size greater than 1 micrometer (Effendi, 2003) [5]. Increased TSS levels reduce sunlight penetration, thereby inhibiting phytoplankton photosynthesis, which is the primary food source for fish and other organisms (Asdak, 2002) [1]. Furthermore, suspended particles can increase water temperature and lower Dissolved Oxygen (DO) levels, threatening the overall health of aquatic organisms. Oceanographic conditions in the downstream Mahakam are highly complex, driven by the interaction between river discharge and tidal movements, which regulate the distribution of suspended materials (Hutabarat & Evans, 1985; Pariwono, 1989; Supangat & Susanna, 2003) [8, 12].

Given these conditions, water quality monitoring requires a Geographic Information System (GIS) approach to facilitate comprehensive spatial analysis (Prahasta, 2009) [9]. This study aims to analyze the concentration of Total Suspended Solids (TSS) and its distribution on the basis of the tides. The research results were evaluated directly against the surface water quality standards referring to the Republic of Indonesia Government Regulation (PPRI) No. 22 year 2021[10].

Materials and Methods

Geographically, the study area was located in the downstream of the Mahakam River, Kutai Kartanegara District, East Kalimantan, specifically situated between S 0°34'26"– 0°34'44" and E 117°16'48"– 117°23'07" (Figure 1).

Study Area

The research was conducted on September 28, 2025, in the downstream area of the Mahakam River, Kutai Kartanegara Regency, East Kalimantan. A total of 15 observation Sampling Sites were established by considering variations in anthropogenic activities and river morphology. The selected locations encompassed industrial shipyard areas, the Handil Terusan tributary inlet, and river sandbars to observe potential TSS accumulation due to shallowing.

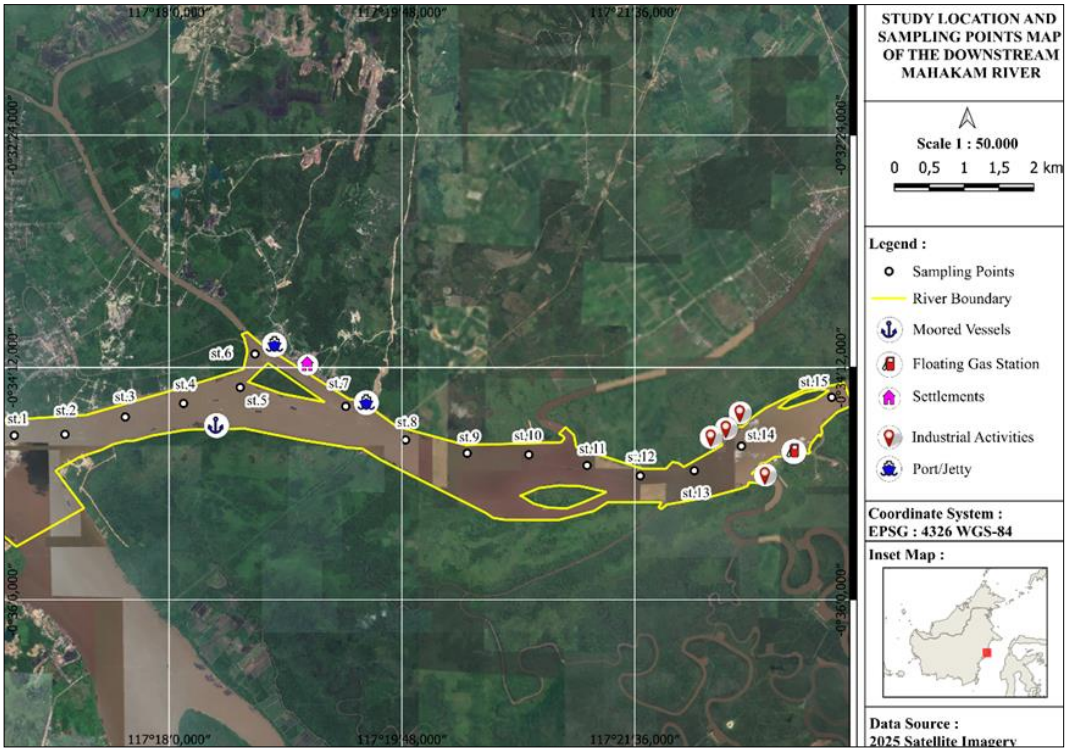

Fig 1: Geographical location of sampling sites in the research location of Mahakam River downstream, Kutai Kartanegara district, East Kalimantan

Data Collection and Laboratory Analysis

Field data collection involved in-situ water quality measurements and surface water sampling. Sampling Site coordinates were determined using a Global Positioning System (GPS). In-situ parameters measured included temperature, salinity, pH, dissolved oxygen (DO), and water transparency, utilizing a water thermometer, refractometer, pH meter, DO meter, and Secchi disk, respectively. Current velocity was measured using the Lagrangian method with a current drogue and stopwatch, recording the travel time over a specific distance (Hasriyanti *et al*., 2015) [6]. Surface water samples for TSS analysis were collected using a water sampler, stored in full 5-liter jerry cans, securely sealed with masking tape, and labeled with a permanent marker. In the laboratory of Water Quality, Faculty of Fisheries and Marine Science, TSS concentrations were analyzed using standard gravimetric procedures according to the Indonesian National Standard (SNI 06-6989.3-2004) utilizing Whatman Grade 42 filter paper, a vacuum pump assembly, a Memmert oven, a desiccator, and a Bel analytical balance.

Data Analysis

A fundamental challenge in this study was that water quality data were only collected from 15 discrete observation points, which is insufficient to visualize the overall distribution across the broad downstream river segment. To solve this spatial problem, the Inverse Distance Weighted (IDW) interpolation method was applied using QGIS software (Version 3.44.5). IDW effectively estimates TSS concentrations in unmeasured locations by assigning distance-based weights to the nearest sampled points, thereby producing a continuous and comprehensive spatial distribution map.

Furthermore, to determine the degree of relationship between physico-chemical parameters (water level, temperature, pH, DO, transparency, and current) and TSS concentrations, a non-parametric Spearman Rank correlation test was performed. The statistical analysis was conducted using Minitab 22 based on the following formula:

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

Where:

rs = is the Spearman correlation coefficient.

di = is the difference in ranks between variables (X - Y).

n = The number of data samples.

Results and Discussion

TSS Concentration and Environmental Compliance

The analysis of water samples across 15 observation Sampling Sites revealed that the Total Suspended Solids (TSS) concentrations ranged from a minimum of 14.88 mg/L (Sampling Site 6) to a maximum of 39.98 mg/L (Sampling Site 10), with an overall average of 26.11 mg/L. The salinity at all observation Sampling Sites was recorded at 0 PSU, indicating a dominant freshwater environment. The complete summary of the physico-chemical parameters measured at each Sampling Site is presented in Table 1.

Table 1: Physico-chemical water quality parameters and TSS concentrations across 15 observation Sampling Sites in the study area

Sampling Site	Water Level (m)	Current Velocity (m/s)	Transparency (m)	DO (mg/L)	pH	Temp (°C)	TSS (mg/L)
1	1.85	0.21	0.20	4.60	5.63	27.70	20.12
2	1.70	0.19	0.20	4.70	6.53	28.10	17.00
3	1.60	0.26	0.17	4.60	6.55	28.10	20.36

Table 2: (Continued)

Sampling Site	Water Level (m)	Current Velocity (m/s)	Transparency (m)	DO (mg/L)	pH	Temp (°C)	TSS (mg/L)
4	1.45	0.29	0.15	4.50	6.09	28.70	23.86
5	1.35	0.28	0.22	4.50	6.40	29.80	24.43
6	1.25	0.27	0.23	4.80	6.05	29.70	14.88
7	0.90	0.31	0.21	4.10	5.99	28.50	38.15
8	0.80	0.26	0.20	4.50	6.05	29.60	24.62
9	0.72	0.34	0.17	4.40	5.93	29.50	29.57
10	0.65	0.36	0.18	4.10	6.10	29.00	39.98
11	0.58	0.37	0.16	4.20	5.61	29.00	35.17
12	0.52	0.41	0.19	4.10	5.97	28.60	39.67
13	0.55	0.41	0.19	4.70	6.10	28.60	17.15
14	0.62	0.36	0.20	4.30	6.21	28.80	30.27
15	0.75	0.39	0.20	4.70	6.22	28.80	16.40

As indicated in the table, despite the intensive anthropogenic activities in the downstream Mahakam River, all observed values remained safely below the maximum permissible limit of 50 mg/L. This threshold is stipulated for Class II surface waters under the Republic of Indonesia Government Regulation (PP) No. 22 year 2021 regarding Environmental Protection and Management.

Spatial Distribution Dynamics

According to the Inverse Distance Weighted (IDW), the TSS concentration was mapped and indicated by colors. A clear visualization of the highest concentration distribution showed the sampling sites 7, 10, 11 and 12 indicated by the dark color zones such as dark brown areas on map. The interpolation model effectively translates localized point data into a continuous spatial surface, offering critical insights into the dispersion patterns of suspended materials across the lower river segment. By applying this spatial analysis, the transition zones between areas of low and high turbidity become evident, revealing how geomorphological features and localized human activities disrupt the natural sediment transport. This visual representation is fundamental for identifying specific zones that require immediate environmental evaluation. The comprehensive visualization of these concentration hotspots across the study area is illustrated in Figure 2.

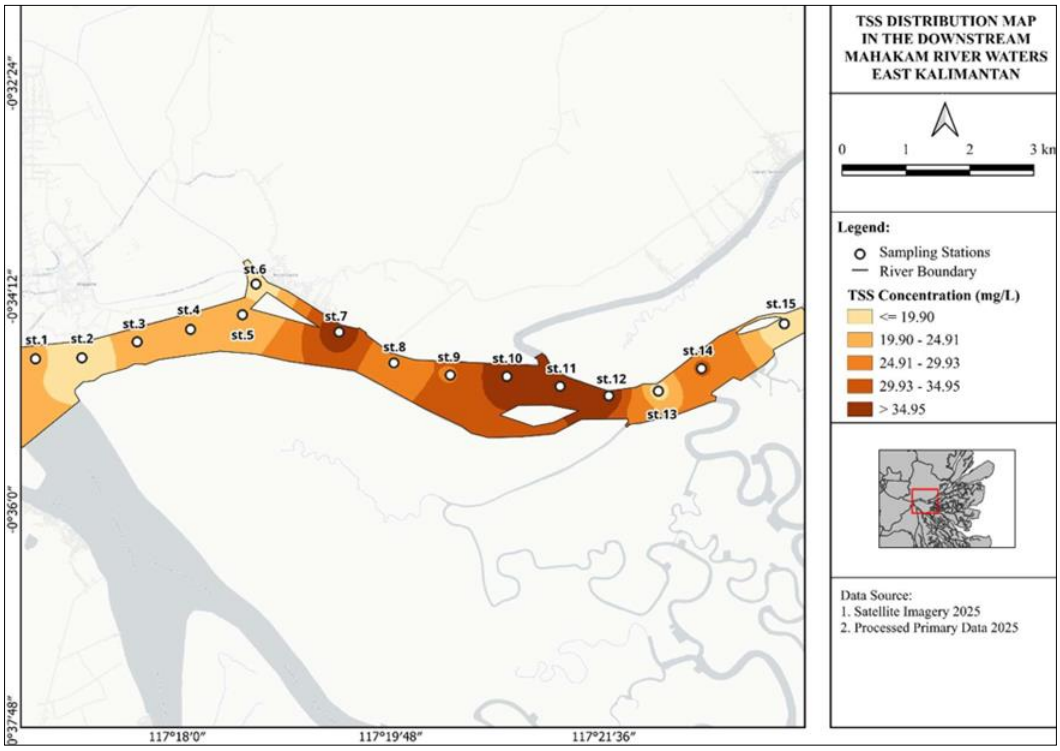

Fig 2: Spatial distribution map of Total Suspended Solids (TSS) of Mahakam River downstream, Kutai Kartanegara district, East Kalimantan Generated using Inverse Distance Weighted (IDW) interpolation

As visually depicted in the interpolation map, a sharp concentration spike was observed at Sampling Site 7 (38.15 mg/L), which is geographically situated at a morphological bottleneck near an island's tip and adjacent to a jetty. As described by Hidayat *et al*. (2011) [7], morphological constraints such as island tips significantly elevate flow turbulence and kinetic energy (recorded at 0.31 m/s in this study). This hydrodynamic condition drives intense bottom sediment resuspension, lifting previously settled particles back into the water column.

Sampling Site 10 recorded the absolute maximum TSS value (39.98 mg/L). Scientifically, this peak is a manifestation of cumulative loading, where sediment materials transported from the upstream Sampling Sites massively accumulate at this specific point. This condition is further exacerbated by extremely high local

anthropogenic intensity, encompassing both domestic waste discharge and heavy navigational traffic, which continuously maintains sediment in a suspended state. Furthermore, high concentrations persisted through Sampling Sites 11 (35.17 mg/L) and 12. Sampling Site 11 functions as the outflow point for the Handil Terusan canal. According to the link channel theory (Rice *et al*., 2001) [11], connecting channels traversing densely populated areas act as significant point sources for the main river. The water mass flowing from this canal brings substantial suspended materials from domestic activities and canal bank erosion. This high sediment load is sustained up to Sampling Site 12, where the existing current energy remains sufficient to prevent particle deposition.

Conversely, a notable phenomenon occurred at Sampling Site 6, which recorded the lowest TSS value (14.88 mg/L) despite its proximity to the Kutai Lama settlement and its location at a current confluence. Based on hydrodynamic principles (Constantinescu *et al*., 2014) [3], this is explained by the dominant momentum ratio (Mr) of the main river flow. The massive water

volume from the upstream Mahakam exerts a dominating momentum that effectively restricts

lateral sediment inputs from the riverbanks, confining them to the mixing interface and preventing their dispersion into the mid-channel flow.

Statistical Correlation with Environmental Parameters

To determine the driving factors behind TSS variability, a Spearman Rank correlation test was conducted. The analysis revealed that Dissolved Oxygen (DO) possesses the strongest relationship with TSS among all measured physico-chemical parameters. The test yielded a correlation coefficient (rs) of -0.988 with a highly significant p-value ($p < 0.01$).

The significant inverse relationship between TSS and DO concentrations across all sampling points is visually summarized in the scatter plot in Figure 3

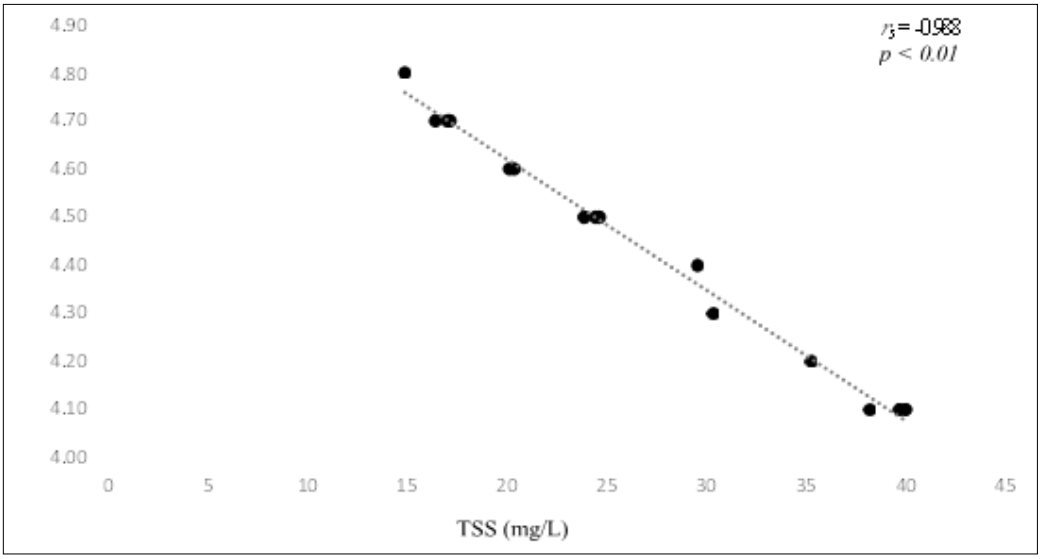

Fig 3: Spearman Rank correlation plot illustrating the strong negative relationship between TSS concentrations and Dissolved Oxygen (DO) (rs = -0.988, $p < 0.01$)

As demonstrated by the steep downward trendline in Figure 3, the data reveals a clear inverse relationship between the variables. Statistically, this indicates a very strong and highly significant negative correlation. This relationship implies that an increase in suspended solids drastically reduces the dissolved oxygen levels in the water column, primarily because high turbidity restricts light penetration, thereby inhibiting the photosynthetic processes of phytoplankton.

Conclusion

The study concluded that the water quality in the downstream Mahakam River, Total Suspended Solids (TSS) concentration was still within the permisibble limit based on the Republic of Indonesia Government Regulation No. 22 year 2021 for river (Class II). The average of TSS concentration was relatively low 26.11 mg/L. The highest TSS concentrations were found near industrial jetties. The correlation between TSS concentration and DO concentration showed the extremely strong negative correlation (rs= -0.988).

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