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ASSESSMENT OF WATER QUALITY PARAMETERS AND THEIR CORRELATIONS IN THE KALIMAS RIVER, SURABAYA: IMPLICATIONS FOR HEALTH RISKS

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Abstract:
The Kalimas River, which flows through industrial and residential areas, faces significant pollution pressure due to diverse anthropogenic activities. This study evaluates the water quality parameters of the Kalimas River in Surabaya, Indonesia, and investigates the correlations among these parameters to assess potential health risks. Key parameters assessed include temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). Sampling was conducted along ten strategically selected segments. The results reveal varying levels of pollution, with elevated BOD5, COD, and TSS values indicating organic and chemical pollution and low DO levels signaling oxygen depletion in certain sections. Statistical analysis using Spearman's correlation demonstrated significant relationships among variables, such as a negative correlation between temperature and DO. Health risks are evident, as high COD and BOD levels promote pathogen growth, increasing the risk of waterborne diseases, while elevated TSS may carry pollutants that further threaten public health. The presence of low DO levels also disrupts aquatic ecosystems, which can exacerbate bacterial growth, posing additional health hazards to communities using the river for daily activities. These findings highlight the need for urgent interventions to mitigate pollution and protect both ecological health and public safety.

Keywords: Health Risk, Kalimas River, Pollution, Water Quality

INTRODUCTION

Rivers play a vital role in the hydrological cycle and serve as essential water sources for domestic, agricultural, industrial, and recreational activities. However, rapid urbanization and industrialization have led to increased pollutant loads in rivers, compromising water quality and posing potential health risks to surrounding communities. The Kalimas River, a prominent waterway in Surabaya, Indonesia, has long been an integral part of the city's ecosystem and urban infrastructure. Despite its importance, the Kalimas River may be subjected to pollution pressures due to its proximity to dense populations, diverse land uses, and various anthropogenic activities.

Assessing the water quality and pollution levels of the Kalimas River is critical to understanding its current status and identifying potential environmental and health risks. Previous studies have shown that pollutants such as heavy metals (Saeed et al., 2023), inorganic and organic contaminants (Rani et al., 2022), and pathogens often exceed permissible limits in urban rivers, leading to adverse effects on both ecological integrity and public health (Owokotomo et al., 2020). In addition, several studies have shown that water sources in Indonesia, including surface and groundwater, are contaminated. Ishak et al. (2022) reported that the levels of heavy metals such as iron (Fe), manganese (Mn), and copper (Cu) in the Martapura River, located in South Kalimantan

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Province, exceeded the limits set by Government Regulation No. 22 of 2021. Another researcher observed that the pollution status of the Cipeusing River in West Java deteriorated over time. In 2016, the pollution index indicated moderate pollution levels, but by 2017, the index values increased significantly, indicating severe pollution (Suriadikusumah et al., 2021).

Water contamination by pollutants is a significant environmental and public health issue due to the adverse effects associated with consuming contaminated water. Heavy metals, for instance, can persist in the environment and bioaccumulate through the food chain, posing risks to human health. Studies by Philips & Fajemila (2024) identified cancer risks in children and adults from exposure to various heavy metals like Co, Pb, Mn, Ni, Cd, Cu, and Zn. Similarly, other researchers found that heavy metals such as Zn, Cu, Pb, Cr, As, and Cd can accumulate in fish, potentially leading to cancer in humans (Hasan et al., 2023).

This study aims to evaluate the Kalimas River's water quality parameters and explore their correlations to assess the potential health risks associated with exposure to these contaminants. The findings will offer valuable insights into the river's ecological dynamics and their implications for the health and well-being of the surrounding community. Ultimately, this research can inform future policy development, guide pollution control strategies, and support sustainable management practices to preserve and enhance the health of the Kalimas River.

METHODS

Conceptual Framework. The study was initially developed based on the idea of examining the relationship between pollution sources and their impact on water quality in the Kalimas River. It focuses on key pollution sources, such as industrial and domestic waste, and their influence on various water quality parameters, including Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). The study then analyzes the correlation between water quality parameters and identifies potential health risks associated with exposure to contaminated water.

Study Area. The research was conducted at Kalimas River, Surabaya, Indonesia (Fig. 1). The Kalimas River begins its flow from the Ngagel area and extends all the way to Tanjung Perak Port in Surabaya City, covering a total length of 13.77 km. The Kalimas River features a mix of winding and straight sections, with its cross-sectional width varying significantly in different areas. In the northern part, the river's width ranges from 20 to 35 meters. The widest section, measuring 35 meters, is located in the Ngagel subdistrict, known for its clean waters, which residents frequently use for bathing and washing. Conversely, the narrowest segments are found in the Bongkaran subdistrict, specifically along Jl. Karet and Jl. Coklat, where the river narrows down to 20 meters.

As it traverses through the heart of Surabaya, the river passes through various regions, including commercial districts, office areas, densely populated residential neighborhoods, and small-scale industrial zones. These areas have the potential to contribute significant pollution to the Kalimas River, impacting its water quality and ecological health. The sampling segments for this study were established along the Kalimas River, starting from the upstream area in Ngagel to the downstream cargo port at Tanjung Perak. A total of 10 segments were defined based on strategic criteria, including accessibility for sample collection, the presence of tributary junctions, river bends, and areas with potential pollution sources. These segment boundaries were selected to ensure a comprehensive representation of the river's pollution profile, enabling a comparative analysis of pollution levels at different points along the river. The chosen sampling locations aim to provide a clearer understanding of how pollution varies throughout the river's flow, from the upstream areas to the heavily industrialized downstream regions.

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Figure 1. Sampling Site

Water Quality Parameters. The water quality parameters assessed included temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). Laboratory analysis was conducted at the Environmental Engineering Laboratory, Faculty of Science and Technology, Islamic State University of Sunan Ampel Surabaya.

Data Collection. The analysis results were evaluated through descriptive analysis, focusing on characterizing the extent of river pollution. This approach involves comparing the findings with those of previous studies by other researchers to offer context and deeper insights.

Statistical Analysis. Statistical analysis was performed using R to identify differences between sites and assess the correlations among various water quality parameters.

RESULT AND DISCUSSION

This section presents the findings from the analysis of water quality parameters in the Kalimas River, Surabaya, focusing on their correlations and potential health implications.

Water Quality of the Kalimas River. The following figure presents the distribution of key water quality parameters—BOD5, COD, DO, pH, temperature, and TSS—across 10 sampling sites along the Kalimas River. These parameters are critical indicators of the river's ecological health and play a significant role in determining water quality.

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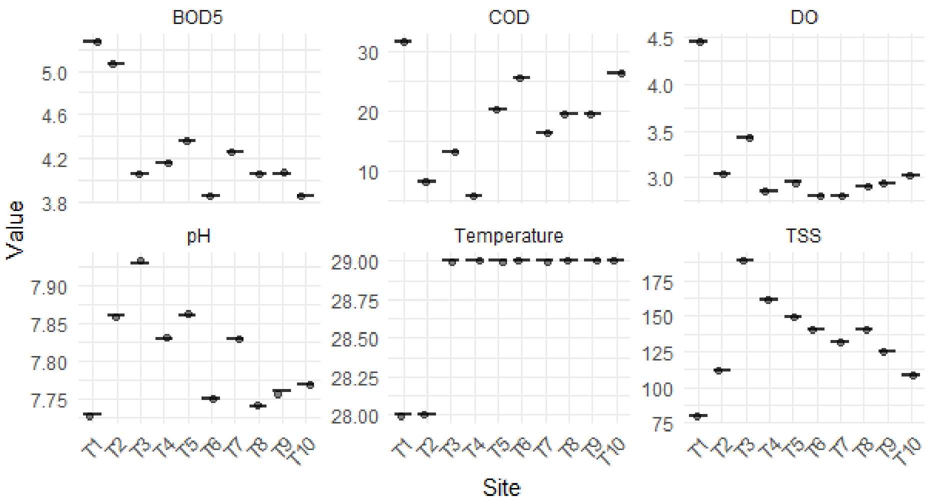

Figure 2. Distribution of Water Quality Parameters Across 10 Sites

The distribution of water quality parameters across the 10 sampling sites along the Kalimas River reveals varying levels of pollution and environmental conditions. BOD5 values range between 3,8 and 5,27 mg/L, with higher values indicating significant organic pollution, possibly from untreated wastewater or decaying organic matter. Similarly, COD levels fluctuate between 5,68 and 31,6 mg/L, suggesting the presence of both biodegradable and non-biodegradable substances from industrial or domestic sources. Some sites exhibit elevated BOD5 and COD values, signaling potential pollution hotspots that could negatively affect aquatic ecosystems. DO concentrations, varying from 2,80 to 4,46 mg/L, are lower in some areas, which may indicate oxygen depletion due to organic matter decomposition or high microbial activity, posing stress to aquatic life.

In contrast, pH levels remain stable between 7,73 and 7,93, suggesting the absence of strong acidic or alkaline pollutants. Water temperature is also consistent across sites, ranging from 28.0°C to 29.0°C, indicating minimal influence from external thermal discharges. However, TSS levels, ranging from 80 to 189 mg/L, show considerable variation, with higher concentrations at some sites likely resulting from increased sediment load or suspended particles. Elevated TSS can reduce light penetration and impair aquatic habitats, leading to ecosystem degradation. These findings highlight spatial variability in water quality, with some areas requiring targeted interventions to mitigate pollution and protect the river's ecological health.

Correlation. Before analyzing the correlations, we generated scatterplots with LOESS curves to identify potential non-linear relationships between pairs of variables. The following scatterplots display the results.

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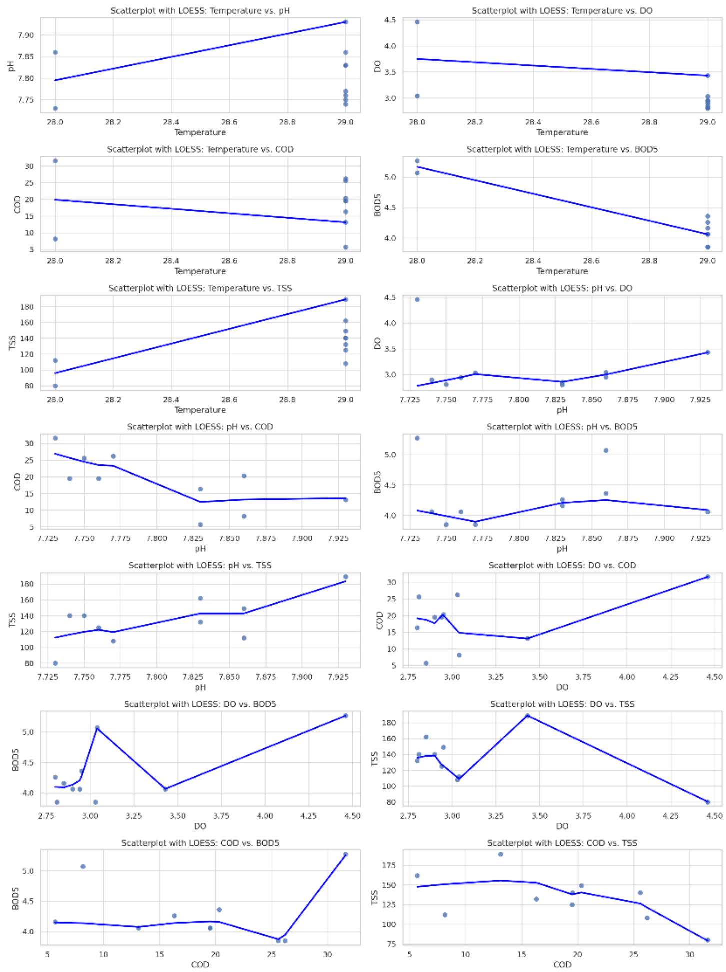

Figure 3. Scatterplots with LOESS Curves

The results of the LOESS curves reveal that the relationships between certain variables (e.g., Temperature vs. BOD5, DO vs. COD) exhibit trends that are not strictly linear. In several cases, the LOESS curves (shown in blue) display slight bends, suggesting the presence of non-linear relationships. Therefore, we proceeded with the Spearman correlation test, which is more appropriate for capturing such non-linear associations. The following are the results of the correlation analysis.

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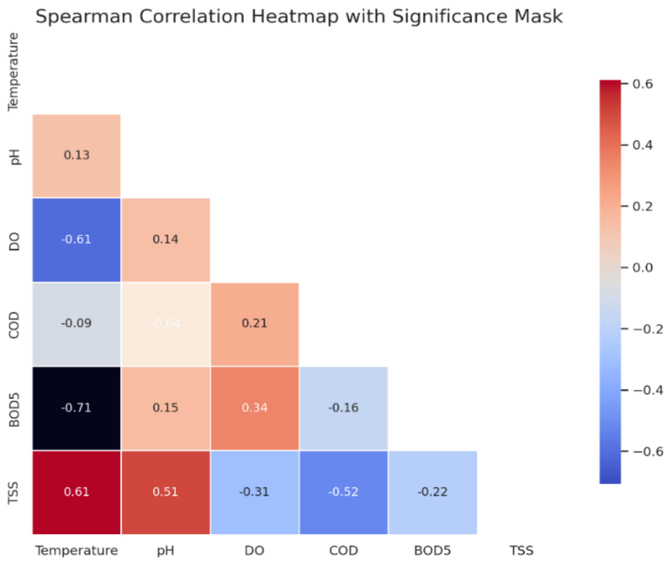

Figure 4. Spearman Correlation Heatmap

The Spearman correlation analysis revealed several significant relationships. A strong negative correlation was observed between BOD5 and Temperature (r = -0.71), indicating that as temperature increases, BOD5 decreases, likely due to accelerated organic matter decomposition at higher temperatures. Different sites may have varying levels of organic load, nutrient availability, or aeration. In sites with better water quality, warmer temperatures enhance decomposition to the point where organic material is rapidly consumed, leaving less to contribute to BOD5 over the measurement period. Conversely, in more polluted sites, higher temperatures might coincide with higher BOD5 values due to persistent organic pollution. A study on inland and coastal waters aligns with earlier research on soils, indicating that the temperature sensitivity of organic matter decomposition varies across sites and tends to be greater for more complex, lower-quality organic matter (Szewczyk et al., 2023). Similarly, DO and Temperature (r = -0.61) showed a moderate negative correlation, suggesting that warmer water holds less dissolved oxygen, which aligns with known temperature-oxygen dynamics. Recent studies confirm that warmer water holds less dissolved oxygen (DO), which is a well-known phenomenon governed by temperature-oxygen dynamics. As temperatures rise, the solubility of oxygen in water decreases, leading to lower DO levels. Additionally, increased temperatures accelerate microbial respiration and organic matter decomposition, which further depletes oxygen (Chapra et al., 2021).

Additionally, TSS and Temperature (r = 0.61) exhibited a positive correlation, meaning warmer conditions may contribute to increased sedimentation or runoff. Previous studies showed that temperature increases can significantly influence suspended solids and sedimentation. Warmer conditions intensify runoff, leading to greater mobilization of suspended solids into water bodies, especially in areas impacted by land-use changes such as urbanization, agriculture, or construction activities. These dynamics enhance TSS (Total Suspended Solids) concentrations, contributing to sedimentation in rivers and streams. Temperature variations, influenced by climate change, also affect sediment deposition, with higher temperatures promoting faster erosion and runoff, resulting in elevated TSS levels (Murphy, 2020).

Lastly, TSS and COD (r = -0.52 demonstrated a moderate negative correlation, implying that higher suspended solids might be associated with lower chemical oxygen demand, potentially due to reduced availability of degradable organic material in suspended particles. Previous experimental

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studies suggested that TSS (Total Suspended Solids) and COD (Chemical Oxygen Demand) exhibit a complex relationship in various water systems. Higher TSS levels can negatively correlate with COD when suspended solids trap or sequester degradable organic materials, reducing their availability for chemical oxidation. This phenomenon is evident in stormwater and wastewater systems, where the presence of suspended particles limits the efficiency of COD removal by hindering the breakdown of easily degradable organic matter during treatment processes. A study conducted on hybrid-constructed wetlands for wastewater treatment demonstrated how TSS removal influences COD removal, indicating that particulate matter and organic content interact dynamically throughout the treatment process (Kim et al., 2018).

The water quality parameters—temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS)—are essential indicators for determining the river's pollution status, assessing health risks, and guiding water quality management strategies. DO is necessary for organisms to metabolize nutrients, BOD measures the oxygen required by organisms to decompose organic compounds, and COD quantifies the oxygen needed to oxidize all organic matter chemically. TSS represents the solid particles that remain suspended in the water and do not pass through filters (Sawyer, 2003).

The water quality data indicates potential health risks due to high levels of COD, BOD5, and TSS combined with low dissolved oxygen. High COD and BOD5 values suggest significant organic pollution, which can promote the growth of harmful pathogens, increasing the risk of waterborne diseases. The low DO levels are detrimental to aquatic life, disrupting the ecosystem and leading to a buildup of harmful bacteria. High TSS can also carry pollutants and pathogens, posing a risk to communities using the water for bathing or other daily activities (Babuji et al., 2023). Recent research indicates that approximately 45% of individuals reported experiencing health-related issues, and over 26% suffered from water-borne diseases following contact with polluted surface water (Haldar et al., 202). These findings highlight the tangible health risks posed by exposure to contaminated water sources, emphasizing the need for urgent measures to protect public health and prevent further incidents. Moreover, prolonged exposure to polluted water, even at minor levels, can cause chronic health issues, especially for vulnerable populations such as children and the elderly (Eid et al., 2024).

River pollution is a complex environmental issue faced by many countries around the world, including Indonesia. It presents a significant challenge due to the diverse sources of contamination, such as industrial discharges, agricultural runoff, and untreated sewage, which threaten water quality and ecosystem health. Addressing river pollution requires coordinated efforts and innovative solutions, as it is not only a local issue but a global concern impacting water resources worldwide.

CONCLUSION

This study demonstrates that the Kalimas River in Surabaya faces significant pollution challenges, posing potential risks to both ecological health and public safety. Key water quality parameters, including BOD5, COD, DO, and TSS, varied across different segments of the river, reflecting the influence of diverse pollution sources. High levels of COD and BOD5 indicate organic and chemical contamination, fostering conditions conducive to the growth of harmful pathogens. Low dissolved oxygen levels further threaten aquatic ecosystems, potentially leading to bacterial proliferation that increases the risk of waterborne diseases. Additionally, elevated TSS levels, which may carry pollutants and pathogens, amplify the public health risks for communities using the river for daily activities. The study's findings emphasize the need for targeted interventions to reduce

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pollution, improve water quality, and safeguard public health. Correlation analysis revealed significant relationships among water quality parameters, such as the negative correlation between temperature and DO, providing insights into the complex interactions affecting river health. Addressing the pollution in the Kalimas River requires coordinated efforts, including pollution control strategies, sustainable water management practices, and policy reforms. Future research and continuous monitoring are recommended to track water quality trends and guide the development of long-term solutions.

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