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ASSESSMENT OF WATER QUALITY PARAMETERS AND THEIR CORRELATIONS IN THE KEMAMBANG RIVER, SIDOARJO, EAST JAVA PROVINCE: A ONE HEALTH FRAMEWORK APPROACH

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Abstract

The river, a vital resource for agricultural, industrial, and domestic use, faces pollution pressures from anthropogenic activities. This study examines the water quality parameters of the Kemambang River in Sidoarjo, East Java, within the context of the One-Health Framework, emphasizing the interconnectedness of environmental, human, and animal health. Sampling conducted at three distinct points along the river revealed spatial variability in key parameters such as Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), temperature, and oil and grease content. Analysis showed that while pH remained within acceptable limits, BOD and oil and grease levels exceeded regulatory standards, particularly downstream, where domestic and agricultural runoff contributed to oxygen depletion. Spearman correlation analysis highlighted strong positive correlations between TSS, COD, and oil and grease, while BOD and COD were negatively correlated with DO, underscoring the impact of pollutants on oxygen dynamics. These findings demonstrate how industrial and domestic activities compromise the river's ecological health, impacting human and aquatic systems. By adopting the One-Health Framework, this study provides a holistic perspective on water quality challenges, offering insights for targeted interventions and sustainable management practices.

Keywords: *Anthropogenic Pollution, One-Health Framework, Water Quality Parameters*

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1. Introduction

Water quality is a critical component of environmental health, directly influencing ecological balance, human livelihoods, and public health. Rivers, as dynamic aquatic

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ecosystems, play a vital role in providing water for agricultural, industrial, and domestic purposes. However, increasing anthropogenic activities, including urbanization, industrial discharges, and agricultural runoff, have led to a decline in water quality thereby posing significant risks to the environment and public health. Previous studies have revealed that numerous contaminants are present in rivers worldwide, posing significant threats to both human and animal health (Li et al. 2022; Anh et al. 2023). In the local context, many rivers have been found to exceed their carrying capacity due to high levels of pollutant content (Mawaddati, Munfarida, and Hakim 2021; Munfarida et al. 2020; Wazna Auvaria and Munfarida 2020). The Kemambang River in Sidoarjo is no exception, serving as a crucial water source while simultaneously being subject to various pollution pressures. This study investigates water quality parameters and their interrelations within a One Health framework, offering insights that are both timely and impactful.

The One Health framework emphasizes the interconnectedness of human, animal, and environmental health (Danasekaran 2024). By adopting this holistic approach, our research seeks to contribute to a comprehensive understanding of how water quality degradation affects not only the ecosystem but also the broader community's health and sustainability. Despite extensive global and regional research on water quality, limited studies have employed the One Health perspective to analyze water quality dynamics and correlations, particularly in Indonesia. Recent studies underscore the significance of such interdisciplinary approaches. For instance, research on riverine ecosystems has increasingly highlighted the necessity of integrating environmental data with public health outcomes to formulate effective mitigation strategies (Soares de Moura et al. 2024; Kuehne et al. 2023)

Identifying and analyzing water quality parameters is crucial, as it can uncover underlying pollution sources and trends essential for targeted interventions and sustainable water management. This research uniquely leverages the One Health framework to address gaps in existing studies that often treat water quality and public health as separate issues. Furthermore, it employs recent methodological advancements, including advanced statistical analyses, to provide a more nuanced understanding of water quality trends.

While previous studies have extensively examined water pollution and its effects, there remains a gap in research explicitly addressing the interplay between multiple water quality parameters and their implications under the One Health paradigm. For instance, previous studies have largely focused on singular aspects, such as the impact of specific pollutants source (Pásková et al. 2024)or the influence of land-use changes (I. Munfarida, Munir, and Rezagama 2020; Gunawardana and McDonald 2024). By contrast, our research integrates these dimensions, offering a holistic perspective that aligns with the latest calls for interdisciplinary research in environmental sciences.

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2. Method

This study employed a systematic approach to assess water quality in the Kemambang River, Sidoarjo. Water samples were collected in accordance with SNI 8995.2021 standards, the Indonesian National Standard established by the National Standardization Agency (BSN) to ensure quality, safety, and consistency. Adhering to these standards ensured standardized and replicable sampling methods, enabling reliable and accurate data collection. Sampling was conducted at multiple sites along the river to capture spatial variability in water quality parameters. The methodology involved strategic sampling, collaboration with certified laboratories for accurate parameter analysis, and statistical and descriptive analyses to explore relationships among key water quality parameters. This approach provided a comprehensive and structured evaluation of the river's ecological health, with findings contextualized within the One-Health Framework.

2.1 Study Area

This study was conducted in the Kemambang River, located in Sidoarjo District, Sidoarjo City, East Java Province. Water sampling was carried out at three points along the river, with samples collected from both sides of the river at each specified point in January 2024. The sampling locations were determined based on the characteristics of the areas drained by the river:

1. Point 1 (Upstream): This site is in a region of rice fields, far from sources of industrial pollutants.
2. Point 2 (Pollution Source): This site is characterized by the presence of a cracker factory industry, which generates liquid waste from the production process.
3. Point 3 (Downstream/Estuary): This site is situated near ponds and residential areas, where domestic liquid waste contributes to pollution.

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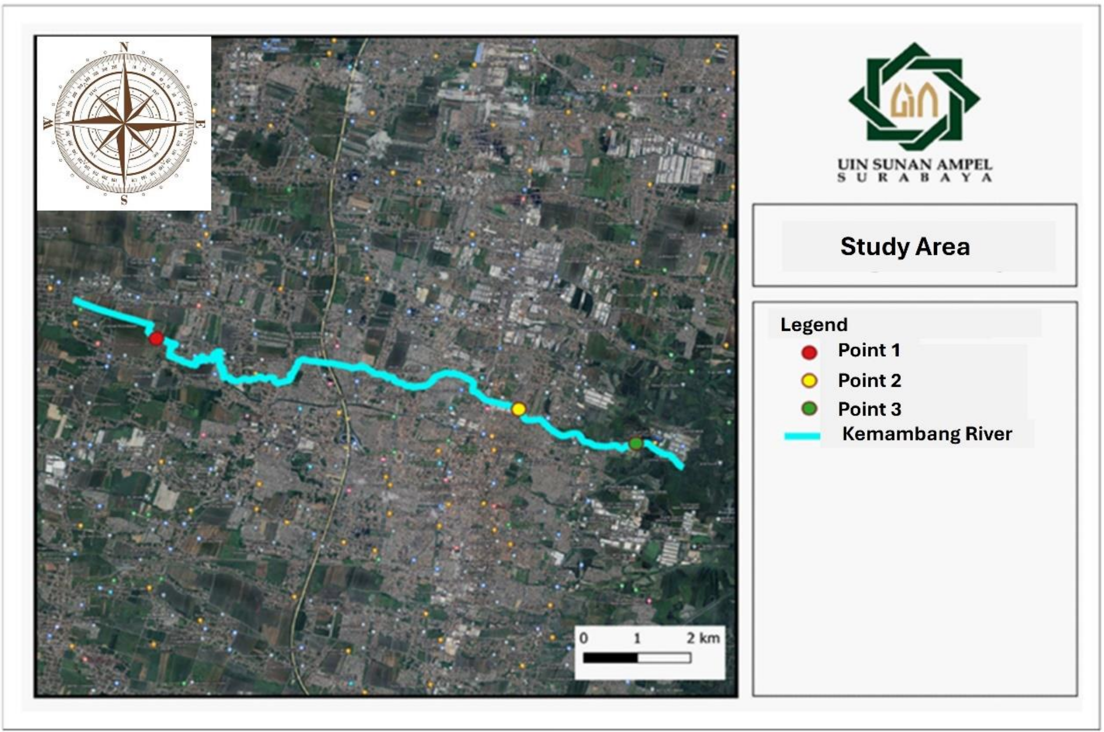

Figure 1: Study Area

2.2 *Sampling Procedure*

Water samples were collected in accordance with SNI 8995.2021 standards, ensuring standardized and replicable sampling methods. Sampling was conducted at multiple sites along the river to capture spatial variability in water quality parameters. The water quality analysis included the measurement of pH, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), temperature, and concentrations of oil and grease. All analyses were performed in collaboration with the East Java Provincial Environmental Service Laboratory, which is equipped with state-of-the-art instrumentation and adheres to quality assurance protocols.

2.3 *Data Analysis*

The results of the parameter analysis were compared to Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Management Protection, and data analysis was conducted using R statistical software. Furthermore, correlation analyses were performed to explore relationships among water quality parameters, providing insights into potential pollution sources and their interactions. Additionally, descriptive analyses were used to interpret findings within the One Health framework, linking environmental data to broader implications for human and animal health.

3. Result and Discussion

The water quality of the Kemambang River was analyzed to evaluate its compliance with the environmental standards outlined in Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Management Protection (Class II). This regulation establishes benchmarks for maintaining water quality to support aquatic ecosystems and other uses such as agriculture and recreation. Advanced statistical tools were utilized to analyze the data, enabling the identification of trends, correlations, and deviations from quality standards. The findings provide a comprehensive understanding of the river's current condition and its potential risks to human and environmental health.

3.1 Water Quality of the Kemambang River

The analysis focused on key water quality parameters, including pH, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), temperature, and oil and grease content. These parameters were selected due to their significance in assessing pollution levels, ecological balance, and public health risks. The sampling was conducted at three distinct points along the river, representing upstream, midstream (near industrial influence), and downstream (near residential areas). Each point provides insights into the spatial variability of water quality and potential sources of contamination. The subsequent data analysis explores the measured values of each parameter across the three sampling points, comparing them to the regulatory standards (Figure 2).

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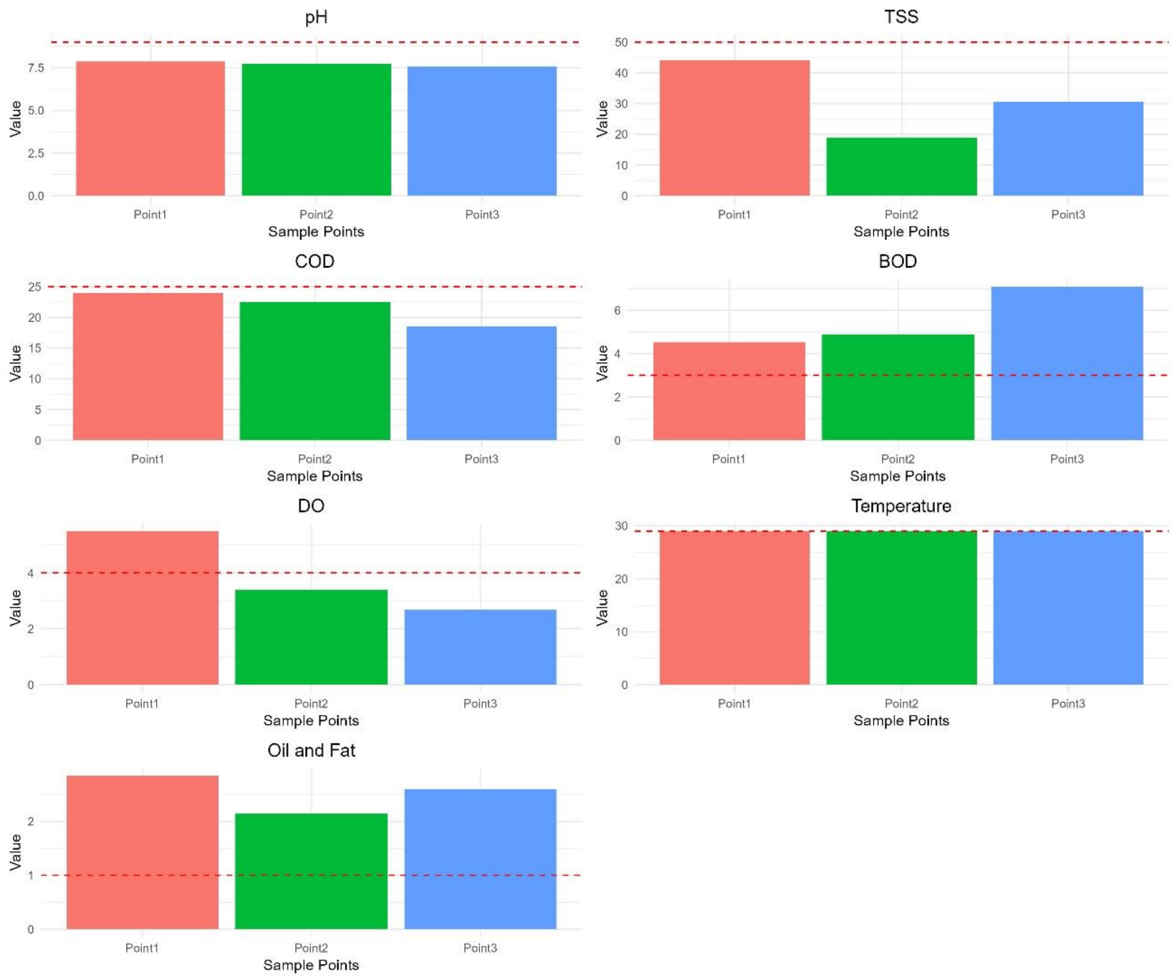

Figure 2: Distribution of Water Quality Parameters Across Sampling Points

The water quality analysis reveals distinct patterns across the three sampling points in the Kemambang River. The pH values across all points fall within the acceptable range (6 to 9), suggesting a stable and neutral water condition throughout the river. However, Total Suspended Solids (TSS) are notably high at Point 1, nearing the quality standard of 50 mg/L, indicating sediment or particulate inflow from upstream sources. Previous study revealed that sediment sources can be derived from organic nitrogen fertilizers and rainfall (Matej-Łukowicz et al. 2023). This statement aligns with our findings, as the upstream site is situated in a region of rice fields, where the use of fertilizers is likely contributing to the observed conditions. In contrast, Points 2 and 3 show significantly lower TSS, likely due to natural sedimentation processes. While the Chemical Oxygen Demand (COD) levels at all points remain below the quality standard of 25 mg/L, the downstream site (Point 3) exhibits the lowest levels, meanwhile the Biochemical Oxygen Demand (BOD) values exceed the quality standard (3 mg/L) at all points, with Point 3 showing the highest levels, indicative of significant organic pollution downstream. This trend is further exacerbated by the Dissolved Oxygen (DO) levels, which are below the standard of 4 mg/L at Points 2 and 3. The consistent temperature of 29°C across all points falls within the permissible deviation range, signaling no evidence of thermal pollution in the river. Oil and grease concentrations exceed the

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quality standard (1 mg/L) across all sampling points, with the highest values observed at Point 1. This indicates possible pollution from upstream industrial or agricultural sources. The elevated BOD and reduced DO levels downstream (Point 3) highlight the impact of domestic and agricultural runoff, which contributes to oxygen depletion and increased organic matter. There is evidence of a degree of self-purification within the river; however, anthropogenic activities surrounding the river may compromise and deteriorate this natural purification system. This observation aligns with findings from previous studies which demonstrated that its self-purification capacity had been significantly impacted by human activities (Novita et al. 2024; Pratiwi et al. 2023)

3.2 Correlation Analysis

Prior to conducting the correlation analysis, scatterplots with LOESS curves were created to explore potential non-linear relationships between variable pairs. The resulting scatterplots are shown in Figure 3.

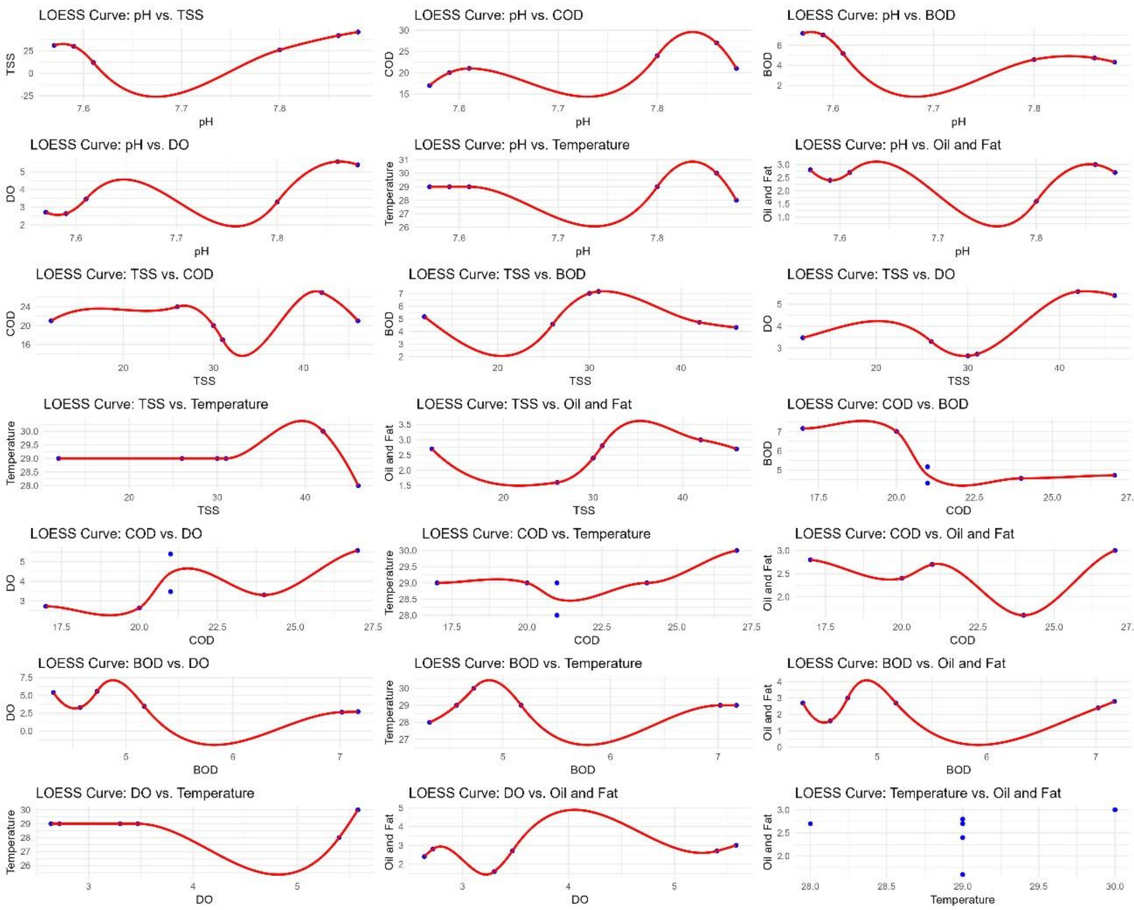

Figure 3: Scatterplots with LOESS Curves

The LOESS curve analysis indicates that certain relationships, such as pH vs. DO, TSS vs. COD, and BOD vs. DO, demonstrate clear non-linear patterns. Many of the curves (depicted in red) show noticeable bends and variations, reflecting complex interactions between the variables. As a result, we conducted a Spearman correlation test, which is more effective in capturing these non-linear associations. The results of the correlation analysis are illustrated in Figure 4.

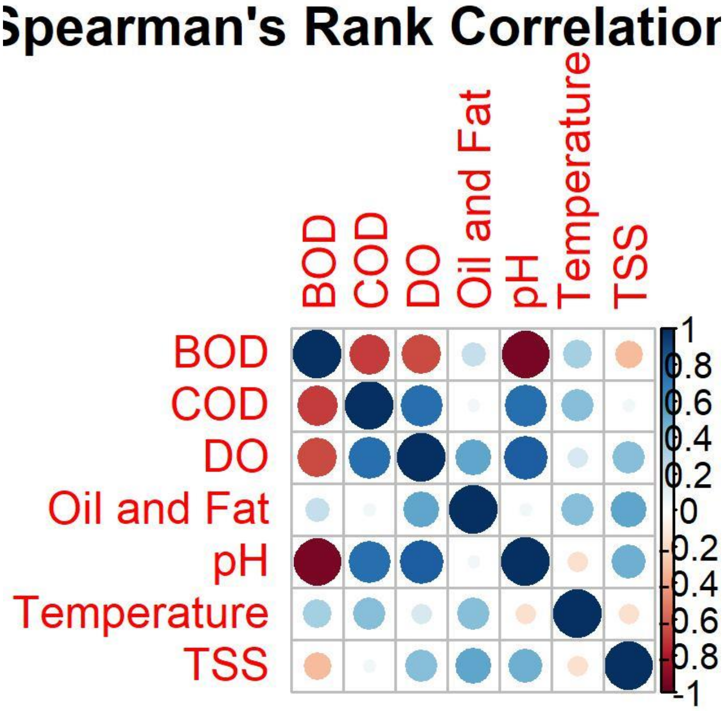

Figure 4: Spearman's Rank Correlation Matrix

The Spearman's Rank Correlation Matrix highlights significant positive correlations between key water quality parameters. A strong positive relationship is evident between Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), indicating that these two measures of organic and chemical pollution often increase together. This result aligns with previous studies, which highlight that anthropogenic activities have the most significant impact on COD and BOD at the catchment scale (Xu et al. 2020) and laundry water (Lacalamita, Mongioví, and Crini 2024). Similarly, TSS (Total Suspended Solids) shows a strong positive correlation with COD and oil and grease content, suggesting that suspended solids may carry pollutants, such as oils and chemicals, into the water system. Previous studies have identified oil and grease contaminants as being predominantly derived from food industries (Shamika, Goutam, and Vincent 2024; Thuan et al. 2024). This aligns with our findings, where Point 2 is characterized by the presence of a cracker factory, which generates liquid waste from its production processes. Similarly, point 3, situated near ponds and residential areas, is impacted by domestic liquid waste, contributing to pollution. These locations are likely significant contributors to the oil and grease contamination observed in the river.

In contrast, the matrix reveals strong negative correlations between BOD, COD, and Dissolved Oxygen (DO). Higher levels of BOD and COD are associated with reduced DO levels, reflecting the oxygen-consuming nature of organic and chemical pollutants during decomposition (Abu Shmeis 2018). A similar negative trend is observed between TSS and DO, indicating that increased sediment levels, likely causing higher turbidity

(Millar, Couperthwaite, and Moodliar 2016), may hinder oxygen exchange or photosynthesis in the water.

Weak correlations are observed between pH and most other parameters, suggesting that pH remains relatively stable and is not strongly influenced by changes in pollutant levels. Temperature also exhibits weak correlations, reflecting its minimal variation across the sampling points. Overall, the analysis emphasizes the critical role of BOD, COD, TSS, and DO in determining water quality, highlighting the need to address organic and chemical pollution to improve aquatic health.

3.3 One-Health Framework Analysis

The water quality findings for the Kemambang River highlight critical intersections between environmental, human, and animal health, aligning with the One-Health Framework that recognizes the interconnectedness of these domains (Pérez-Martín and Esquivel-Martín 2024). Each parameter analyzed provides insights into potential health risks and environmental impacts resulting from anthropogenic activities.

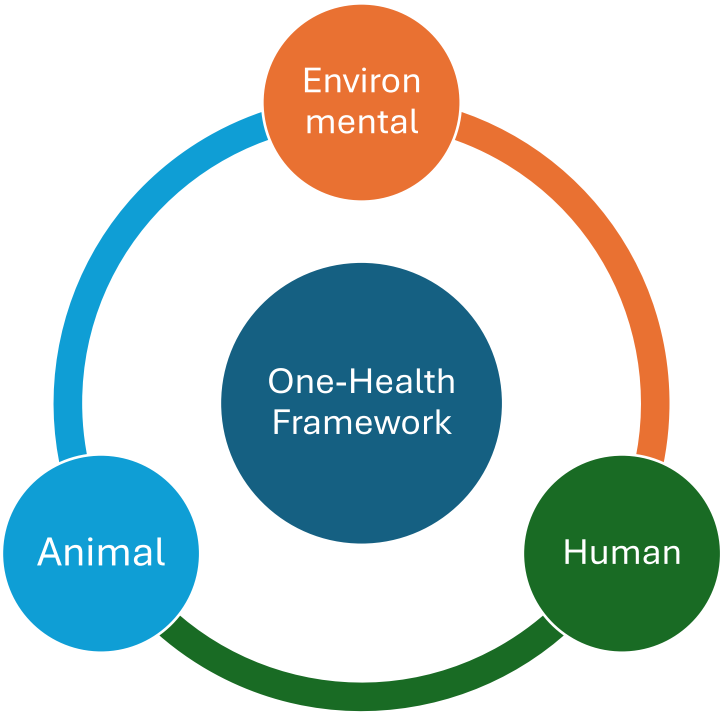

Figure 5: One-Health Framework Analysis

The analysis shows evidence of sedimentation and organic pollution affecting the river's ecosystem. High Total Suspended Solids (TSS) at Point 1, attributed to upstream activities such as organic nitrogen fertilizer use and rainfall, suggests potential soil erosion and agricultural runoff. While natural sedimentation processes mitigate TSS levels downstream, the presence of elevated oil and grease across all points indicates industrial and agricultural contributions to pollution. Elevated Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels highlight the organic and

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chemical load in the river, with a strong positive correlation indicating the interplay of these pollutants. Dissolved Oxygen (DO) depletion at Points 2 and 3 further signifies the inability of aquatic ecosystems to sustain healthy oxygen levels, potentially harming aquatic biodiversity. These findings align with previous studies that show human activities significantly compromising the self-purification capacity of river ecosystems.

Furthermore, the contamination of the river with oil and grease exceeding the quality standard (1 mg/L) poses risks to human health, particularly through water usage for domestic and agricultural purposes. Previous studies revealed that high content of oil and grease have the ecological risk (Hossain et al. 2024) and cannot be used as drinking water sources (Sari et al. 2024). Industrial effluents at Point 2 (cracker factory waste) and domestic liquid waste at Point 3 (residential and pond areas) are primary contributors to this contamination. This aligns with findings that anthropogenic activities, including industrial discharge and domestic effluents, significantly influence COD and BOD levels, potentially degrading water quality at the catchment scale. The elevated BOD and reduced DO downstream suggest the accumulation of organic pollutants that may lead to pathogen proliferation, increasing the risk of waterborne diseases (Bashir et al. 2020). The strong correlation between TSS and COD further emphasizes the role of suspended particles in transporting harmful chemicals, increasing the potential for human exposure to toxins (Rajasekar et al. 2024).

In addition, aquatic organisms are particularly vulnerable to the observed low DO levels at Points 2 and 3, which fall below the quality standard of 4 mg/L. Oxygen depletion can stress aquatic life, hinder reproduction, and, in extreme cases, lead to the death of aquatic organisms. High TSS levels at Point 1, though mitigated downstream, can impair organ function in aquatic organisms and reduce photosynthesis by increasing turbidity. Furthermore, the strong positive correlation between TSS and oil and grease suggest that suspended particles may absorb pollutants, further exacerbating the impact on aquatic life. The consistent temperature of 29°C across all points does not indicate thermal pollution, but the interplay of organic and chemical pollutants threatens the overall health of the aquatic ecosystem, with cascading effects on animals reliant on the river. Previous studies have shown that aquatic organisms rely on the aquatic health and their distribution are different among clean, moderate and polluted river (Robbi et al. 2024; Yudhistira, Munfarida, and Setyowati 2022; Russo, Munfarida, and Setyowati 2024).

To address the water quality issues in the Kemambang River, targeted interventions and sustainable management practices are essential. Industrial pollution control measures, such as stricter regulations and the installation of wastewater treatment systems, are necessary to mitigate oil and grease contamination, particularly from industries like the cracker factory near Point 2. In agriculture, promoting the use of organic fertilizers and erosion control practices can minimize nutrient runoff and reduce Total Suspended Solids (TSS) from upstream areas. Enhancing domestic wastewater treatment infrastructure near Point 3 and educating communities on proper waste disposal can further reduce organic pollutants and improve water quality. Integrated Water Resource Management (IWRM) should be implemented, involving all stakeholders to collaboratively monitor and manage water resources. Riparian zone

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restoration using native vegetation can act as a natural filter, reducing sediment and pollutant loads, while public awareness campaigns can encourage sustainable practices in agriculture and waste management. Strengthening policies and incentivizing sustainable practices can foster collaboration between industries, communities, and government agencies. Additionally, enhancing the river's self-purification capacity through solutions such as constructed wetlands or artificial aeration can improve Dissolved Oxygen (DO) levels. These measures collectively aim to restore the river's ecological health and ensure its sustainability for agricultural, industrial, and domestic use.

This study provides valuable insights into the Kemambang River's water quality, but it is limited to using only three sampling points and data collection during a single season, which may not fully capture spatial and seasonal variability. Additionally, the focus on selected water quality parameters may exclude other relevant pollutants or ecological factors affecting the river ecosystem. These limitations should be addressed in future research to provide a more holistic understanding of the river's health and its interactions with surrounding environments.

4. Conclusion

This study highlights the significant impact of anthropogenic activities on the water quality of the Kemambang River, as assessed through the One-Health Framework. Elevated levels of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil and grease, and Total Suspended Solids (TSS) across various sampling points reflect the contributions of industrial, agricultural, and domestic waste to pollution. Dissolved Oxygen (DO) depletion downstream underscores the compounded effects of organic and chemical pollutants on aquatic health, while strong correlations between key parameters reveal the interconnected dynamics of riverine pollution. These findings emphasize the need for targeted interventions, including stricter industrial discharge regulations, improved wastewater management, and sustainable agricultural practices, to safeguard the river’s ecological health. However, this study is limited by its spatial and temporal scope, as only three sampling points were considered, and data were collected during a single season, which may not fully capture spatial and seasonal variability. Future research should focus on longitudinal monitoring to better understand seasonal and long-term trends, as well as the implementation of nature-based solutions to enhance the river’s self-purification capacity.

5. Acknowledgment

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